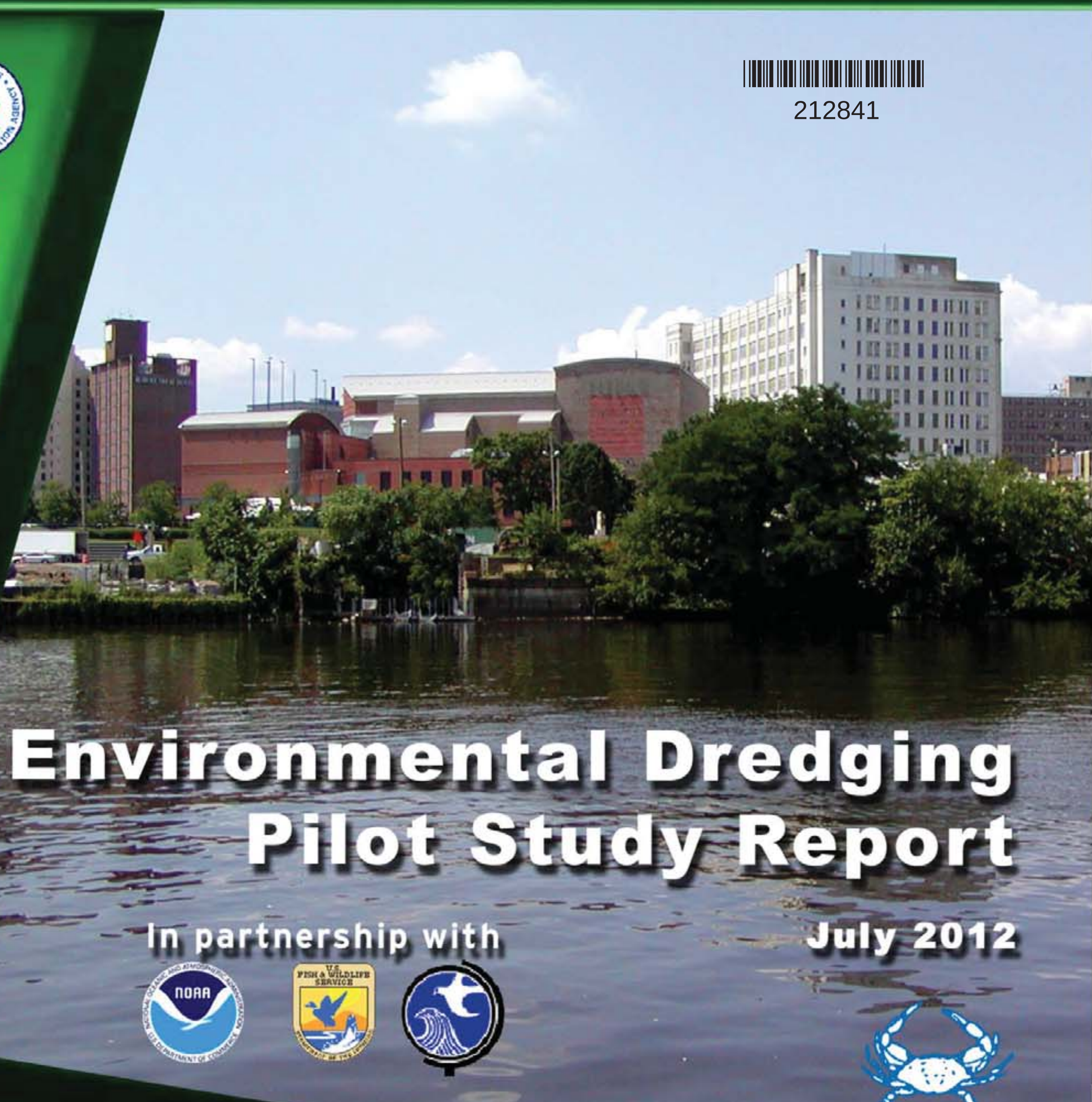
Lower Passaic River Restoration Project



Environmental Dredging Pilot Study Report

In partnership with

July 2012

ENVIRONMENTAL DREDGING PILOT STUDY REPORT
LOWER PASSAIC RIVER RESTORATION PROJECT

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CONTRIBUTORS

This Environmental Dredging Pilot Study was conducted by a highly coordinated technical team of experts from agencies, consultants, universities, and stakeholders. The many contributors and their primary role for this program are acknowledged below.

Agencies and Organizations	
New Jersey Department of Transportation (NJDOT)	Overall management, funding, and Decontamination Pilot
United States Army Corps of Engineers (USACE)	Technical assistance, construction oversight, and field implementation
United States Environmental Protection Agency (USEPA)	Technical assistance, analytical services, and Decontamination Pilot
United States Fish and Wildlife Services (USFWS)	Field Implementation
New Jersey Department of Environmental Protection (NJDEP)	Permitting and technical assistance
United States Geologic Survey (USGS)	Water Quality Monitoring Program
National Oceanic & Atmospheric Administration (NOAA)	Technical Assistance
Rutgers University	Water Quality Monitoring Program
Passaic Valley Sewerage Commissioners (PVSC)	Facility access and use

Consultant Team	
TAMS Consultants, Inc., an Earth Tech Company (TAMS/ET, now AECOM/Earth Tech)	Planning, field implementation, dredging construction oversight, and report preparation
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1.0 INTRODUCTION

The Environmental Dredging Pilot Study (herein referred to as the Pilot Study) was conducted to support the remedial investigation and feasibility study for the Lower Passaic River Restoration Project, which is an interagency study being performed to develop an approach to remediate and restore the Lower Passaic River. The Pilot Study was planned and implemented through a highly coordinated partnering effort integrating the work of agencies, consultants, universities, and stakeholders (Baron *et al*, 2005). The many contributors to this project are acknowledged in the preface pages of this document and listed in Table 1-1. An organization chart is presented in Figure 1-1.

The Pilot Study was conducted in accordance with approved project plans [TAMS Consultants, Inc., *an Earth Tech Company* (TAMS/ET) and Malcolm Pirnie, Inc., 2005a], including the Work Plan, Quality Assurance Project Plan (QAPP), and Health and Safety Plan (HASP). These plans and additional documents can be found on the public website www.ourpassaic.org.

1.1 AUTHORIZATION

The Lower Passaic River Restoration Project (herein referred to as the Study) is an interagency effort to remediate and restore the complex ecosystem for a portion of the Passaic River identified as the Lower Passaic River, which is the 17-mile, tidally-influenced portion of the river located in northeastern New Jersey. The Study Area (118 square miles) is defined as the Lower Passaic River and its basin, which comprises the tidally-influenced portion of the river from the Dundee Dam [river mile (RM)17.4] to Newark Bay (RM0) and the watershed of this river portion, including its tributaries: Saddle River, Second River, and Third River (Figure 1-2). The Upper Passaic River watershed (the area impacting the portion of the Passaic River located above the Dundee Dam) is represented as a point source with solids, water, and contaminants crossing over the dam into the Study Area.

The partner agencies, which include the United States Environmental Protection Agency (USEPA), United States Army Corps of Engineers (USACE), and New Jersey Department of Transportation (NJDOT-local sponsor), are bringing together the authorities of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Water Resources Development Act (WRDA) to produce a comprehensive watershed-based solution to improve water quality, address contaminated sediments, and restore and create habitat along the river. The partner agencies are also working with the federal and state agencies, including the National Oceanic and Atmospheric Administration (NOAA), United States Fish and Wildlife Services (USFWS), and New Jersey Department of Environmental Protection (NJDEP), so that natural resource damages pursuant CERCLA are addressed in this comprehensive plan. The comprehensive remediation and restoration of the Lower Passaic River is also an important component of the Comprehensive Restoration Plan for Hudson-Raritan Estuary (USACE, 2009).

The Lower Passaic River is one of eight urban waterways that have been designated as pilot projects to demonstrate the planning and implementation of urban river cleanups and restoration as part of the Urban River Restoration Initiative (URRI). This URRI program is a national initiative to foster cooperation between USEPA and the USACE and is memorialized in a Memorandum of Understanding between these two agencies, which was signed in 2002 and renewed in 2005.

1.2 PURPOSE OF THE PILOT STUDY

The Pilot Study was designed to yield information on dredging performance and sediment resuspension associated with production environmental dredging, operating with one mechanical dredge system. The Pilot Study was conducted between December 5, 2005 and December 10, 2005 between RM2.6 and RM3.0 on the Lower Passaic River. The Pilot Study involved the removal of approximately 4,000 ±200 cubic yards of dredged material from an area covering 1.2 acres (approximate dimensions of 170 feet wide by 290 feet long). The project was designed to target elevations of 11 feet mean low water (MLW), 13 feet MLW, and 15 feet MLW.

The decontamination demonstration aspect of the Pilot Study, which included an assessment of treatability and beneficial use of contaminated sediment, was implemented by USEPA and NJDOT under the New Jersey-New York Harbor Sediment Decontamination Technology Demonstration Program. The decontamination vendor reports were published under separate cover by others and are currently available on the public website www.bnl.gov/wrdadcon. Consequently, this document only presents results from the environmental dredging pilot (in-water) activities, not treatability.

The major objectives of the Pilot Study, which are specific to the dredging technology tested and the site examined, include:

- Evaluate dredging equipment performance: This objective includes productivity, vertical accuracy (achieving targeted dredging depth and cut lines), and operational controls.
- Monitor sediment resuspension: This objective includes an evaluation of how much sediment and associated contamination are resuspended or otherwise released by the dredging operation.

Analyses conducted to evaluate these dredging-related objectives include dredging productivity calculations, working time analysis, accuracy comparisons, determination of the resuspension production and net suspended sediment flux, and export rates occurring during dredging operations.

1.3 DATA LIMITATIONS OF THE PILOT STUDY

The objective of the Pilot Study was to collect data to evaluate dredging equipment performance and to monitor sediment resuspension in the Lower Passaic River. Data collected during the Pilot Study are summarized below. Details on how these data were collected and utilized as well as any limitations on the data are discussed in the referenced sections, where appropriate:

- Bathymetric Data: Pre-dredging, post-dredging, and daily bathymetric surveys were conducted as part of the Pilot Study (refer to Section 4.6 for description of bathymetric surveys). These data were used to calculated sediment removal volumes (refer to Section 5.3) and to evaluate dredging accuracy (refer to Section 5.5).
- Sediment Profile Imagery (SPI): SPI technology was used to evaluate residuals in the dredging area (refer to Sections 4.7 and 8.4).
- Dredging Contractor Records: Records from the dredging operation are available in the *Final Completion Report* (Jay Cashman, Inc., 2005a; Appendix A). These records include dredging contractor field logs (*e.g.* Daily Activity Summary); e*x-situ* volume measurements (daily estimates of ullage); and ClamVision® data logs. Video footage of the dredging operations was also recorded. Together, these data were used to evaluate dredging equipment performance (refer to Sections 5.1, 5.2, and 5.4). Dredging contractor data were supplemented with the oversight engineer's field notes.
- Hydrodynamic Data: Hydrodynamic data were collected to evaluate sediment resuspension from the dredging activities. The hydrodynamic monitoring program is described in Section 6.1, and the results are presented in Section 7.1 and Sections 8.1 through 8.3.
- Water Quality Data: Water quality was monitored during the Pilot Study. The water quality monitoring program is described in Section 6.2 and the results (including an assessment of data confidence and usability) are presented in Section 7.2 and Section 8.5.

Since the Pilot Study was not intended to report on a full-scale operation, data typically reported for a full-scale operation were not collected during the Pilot Study. Examples of performances or evaluations not addressed during the Pilot Study include:

- Dredging performance calculations (other than maximum operating production rate and average operating production rate).
- Dredging performance in other areas of the river, including near bulkheads, bridge abutments, and utility crossings.
- Dredging performance at other targeted elevations and dredging of sediments with contaminant levels that are higher than those concentrations observed in the Pilot Study Area.
- Impacts and/or health and safety for nighttime dredging operation.
- Performance of alternative dredging technologies and buckets.
- Performance of other remedial alternatives, such as capping or *in-situ* technologies.
- Evaluation of clean-up passes or the removal of a thin layer of contaminated sediments left behind after the initial dredging activity to reach a clean-up goal.
- Evaluation of residuals or the post-dredging surface sediment concentration (with the exception of information obtained from SPI).
- Assessment of horizontal positioning of the bucket and positioning of the dredge area.
- Impacts on water quality when more than one dredging system is operating.
- Debris removal or monitoring.
- Resuspension related to debris removal.
- Costs for a full-scale dredging operation.
- Quality of life issues, including air, noise, and navigational traffic impacts.

While extensive monitoring and performance data were collected during the Pilot Study, these data have limitations, which have been recognized. Furthermore, the data obtained from the Pilot Study are site-specific to the Lower Passaic River at the time of dredging operations. Consequently, the Pilot Study data may not be fully representative of the physical and environmental conditions under which a full-scale dredging operation may be conducted. However, the results of the Pilot Study do provide a basis from which assumptions for a full-scale dredging operation can be made. The scalability of the data and their applicability to a full-scale dredging operation should be evaluated as it is incorporated to other documents. The feasibility study for the Lower Passaic River as well as the *Focused Feasibility Study for the Lower Eight Miles of the Lower Passaic River* (The Louis Berger Group, Inc., anticipated December 2012) will incorporate the Pilot Study results as well as other literature data to develop a general approach for a full-scale dredging operation.

1.4 PREPARATION FOR THE PILOT STUDY

The partner agencies conducted an extensive data collection effort in preparation for the Pilot Study. These preparatory studies included: an environmental dredging technology review, geophysical surveys, sediment coring, hydrodynamic studies, and predictive plume modeling. Data gathered during these preparatory studies were used to design and support the Pilot Study.

The environmental dredging review was conducted to assess the various dredging technologies and their potential application for the Pilot Study (TAMS/ET and Malcolm Pirnie, Inc., 2004a). Based on this review, mechanical dredging systems had several advantages over hydraulic dredging systems for the Pilot Study operation. For example, mechanical dredging entrains less water, which makes this technology more suitable for subsequent thermal treatment. Water storage treatment and the presence of debris were also major reasons why mechanical dredging was selected for the Pilot Study (refer to Section 3.2 for further discussion).

The geophysical surveys included a bathymetric survey, side-scan sonar survey, magnetometer survey, and sub-bottom profiler survey (TAMS/ET and Malcolm Pirnie, Inc., 2005b). The bathymetric survey was conducted to characterize the general water depths and identify the major morphological features (*e.g.*, channel, shoal, and mudflats) in the Pilot Study Area. The side-scan sonar survey was conducted to characterize the surficial sediment texture and identify surficial targets in the Pilot Study Area. The magnetometer and sub-bottom profiler surveys were conducted to detect buried ferrous and non-ferrous objects, to supplement the side-scan sonar data, and to comply with the National Historic Preservation Act and the Abandoned Shipwreck Act (refer to Section 3.4 for further discussion).

The coring analysis was conducted to characterize the nature of contamination within the dredge area and to provide geotechnical information (refer to Section 3.5 for further discussion; TAMS/ET and Malcolm Pirnie, Inc., 2005b). A preliminary hydrodynamic and sediment transport model was also developed to determine the optimal locations for positioning water column monitoring equipment, to estimate the mass flux of sediment leaving the dredge area, and to evaluate the impacts of dredging on suspended sediment levels (refer to Section 3.3 for further discussion; TAMS/ET, 2005).

1.5 DOCUMENT CONTENT

This document is divided into the following sections to describe the Pilot Study.

Section 1.0, "INTRODUCTION": explains the purpose and objectives of the Pilot Study, which are specific to the dredging technology tested and site examined.

Section 2.0, "CHARACTERIZATION OF THE LOWER PASSAIC RIVER": characterizes the Lower Passaic River and provides background information on the area.

Section 3.0, "PREPARATION AND DESIGN OF PILOT STUDY": describes the criteria used to select the site for the Pilot Study, preparatory studies and field work conducted to support the Pilot Study, and the design of the Pilot Study.

Section 4.0, "DREDGING OPERATION": describes the mobilization and associated dredging operations that occurred during the Pilot Study, including Best Management Practices, bathymetric surveys, health and safety, and deviations from the planning documents.

Section 5.0, "DREDGING PERFORMANCE": evaluates the cycle time, work time, estimated volume of sediments removed, productivity, and accuracy to assess the dredging performance of the Pilot Study.

Section 6.0, "MONITORING PROGRAMS": outlines the monitoring field programs, including the hydrodynamic monitoring program and the water quality monitoring program, and documents deviations from the planning documents.

Section 7.0, "COLLECTED MONITORING DATA": presents the data collected during the monitoring field programs, including the hydrodynamic monitoring program and the water quality monitoring program.

Section 8.0, "RESUSPENSION AND SUSPENDED SEDIMENT FLUX": provides an interpretation of the Pilot Study results to evaluate the impacts of dredging operations on resuspension and water quality.

Section 9.0, "CONCLUSIONS": provides a summary of findings from the Pilot Study.

Section 10.0, "ACRONYMS": defines the acronyms used in this document.

Section 11.0, "REFERENCES": provides a list of references cited in this document.

2.0 CHARACTERIZATION OF THE LOWER PASSAIC RIVER

The following section provides background and characterizes the Lower Passaic River, its watershed, and sediments (Figure 1-2). A full discussion of the conceptual site model for the Lower Passaic River is provided in the *Focused Feasibility Study for the Lower Eight Miles of the Lower Passaic River* (The Louis Berger Group, Inc., anticipated December 2012).

2.1 CLIMATE

The climate for the Lower Passaic River and surrounding area is characteristic of the Middle Atlantic Seaboard where marked changes in weather are frequent, particularly in the spring and fall seasons (USACE, 1987). Precipitation is moderate and distributed fairly uniformly throughout the year, averaging approximately 47 inches annually with an average of 121 precipitation days per year. However, the region may be influenced by seasonal tropical storms and hurricanes between June and November. Thunderstorm activity is most likely to occur in the summer. Winters are moderate with snowfall averaging approximately 34 inches annually from October through mid-April. Nor'easters usually occur from November to April; these events usually bring strong northeast winds as they move northward along the Atlantic Coast, leading to heavy rain, snow, and coastal flooding. The average annual temperature in Newark, New Jersey is 54 degrees Fahrenheit (ºF) with extremes from -26ºF to +108ºF. Mean relative humidity varies from 67 to 73 percent. Prevailing winds in the Newark area are from the southwest with only small seasonal variations in direction. The mean wind direction for the winter months is west-northwest (13 percent of the time) while southwest winds (12 percent of the time) predominate during summer. Mean winds speeds are generally highest during the winter and spring months [10 to 12 miles per hour (mph)], and lowest during the summer months (8 to 9 mph), with an average annual velocity of approximately 10 mph.

2.2 GEOLOGY

The Lower Passaic River is situated within the Newark Basin portion of the Piedmont physiographic province. The province is located between the Atlantic Coastal Province and the Appalachian Province. The Newark Basin is underlain by sedimentary rocks (sandstones, shale, limy shale, and conglomerates), igneous rocks (basalt and diabase), and metamorphic rocks (schist and gneiss). These rocks are from the mid-Triassic to early Jurassic periods. Bedrock underlying the area is the Passaic Formation (Olsen *et al.*, 1984; Nichols, 1968), which consists of interbedded red-brown sandstones and shale. Almost the entire Passaic River Basin was subjected to glacial erosion and deposition as a result of the last stage of the Wisconsin glaciation. Considerable quantities of stratified sand, silt, gravel, and clay were deposited in a glacial lake covering the area. These glaciofluvial deposits overlie bedrock and underlie the meadowlands section of the Newark Basin.

2.3 HYDROLOGY

The Lower Passaic River is tidally influenced for its entire length, extending from Dundee Dam downriver to the confluence with Newark Bay. The mean tidal range [difference in height between mean high water (MHW) and MLW] at the New Jersey Turnpike Bridge (approximately 1.5 miles upriver from Newark Bay) is 5.1 feet (NOAA, 1972) with a mean tide level (midway between MLW and MHW) at elevation 2.5 feet (NOAA, 1972). The mean spring tide range (average semi-diurnal range occurring during the full and new moon periods) is 6.1 feet.

Coastal storms are the dominant source of floods on the Lower Passaic River. The Federal Emergency Management Agency Flood Insurance Study for the Town of Harrison indicates an annual tide elevation of 5.7 feet National Geodetic Vertical Datum 1929 (NGVD29). For a two-year recurrence interval, the predicted tide is 6.2 feet NGVD29. Additional predicted tide elevations are 6.9 feet for a 5 year recurrence, 7.5 feet for a 10-year recurrence, 8.2 feet for a 20-year recurrence, 9.3 feet for a 50-year recurrence, and 10.2 feet for a 100-year recurrence interval (tide elevations are referenced to NGVD29). The maximum-recorded tide level on the Lower Passaic River is 8.33 feet, measured at East Newark on September 12, 1960, and is equivalent to a flood with a 20-year recurrence interval. During the record flood of October 1903, the Lower Passaic River crested between 9 and 10 feet in the vicinity of Harrison, New Jersey.

2.4 LAND USE

The banks and wetlands of the Lower Passaic River have long been impacted by industrial activity and commercial and residential growth. More than 7,500 acres of wetlands and floodplains have been developed since 1940 (USACE, 1987). Approximately 40 acres of the original wetland area remain. By the turn of the twentieth century, Newark was the largest industrial-based city in the United States with well-established industries such as petroleum refining, shipping, tanneries, creosote wood preservers, metal recyclers, and manufacturing of materials such as rubber, rope, textiles, paints and dyes, pharmaceutical, raw chemicals, leather, and paper products (Meyers, 1945; Cunningham, 1954; Cunningham, 1966a; Brydon, 1974; Halle, 1984; MacRae, 1986; Galishoff, 1988). Land use along the Lower Passaic River, extending south of the Dundee Dam, is dominated by high-density commercial and industrial/commercial development.

2.5 NAVIGATIONAL USE

The Lower Passaic River was channelized to serve as a federal navigation channel from RM0 to RM15 with the earliest dredging initiated in 1883 to support the many industries located on its banks. As the industries waned in the last half of the twentieth century, the channel ceased to be maintained over much of its length. Specifically, the Harrison Reach of the Lower Passaic River (RM2.5 to RM4.6) was last maintained in 1937, while the last maintenance dredging project completed by the USACE was in 1983 below RM1.9 (USACE, 2010).

Reflecting this decline in use, the State of New Jersey petitioned the United States Coast Guard in 1998 to allow for longer notice times to open the drawbridges since there had been few requests to open them in previous years. After a comment period, the United

States Coast Guard agreed to the petitions. Refer to Table 2-1 for bridges located on the Lower Passaic River and required notice times to open.

Along with industry, commercial traffic on the Lower Passaic River has also declined over the twentieth century. However, recently commercial traffic has started to rise. The *Lower Passaic River Commercial Navigation Analysis* (USACE, 2010) shows that from 1980 to 1999 the volume of commerce has generally decreased, peaking at roughly 9.5 million tons in 1982 and reaching a low of about 1.5 million tons in 1999. Since 1999, the volume of commerce has been rising, reaching just over 4 million tons in 2006. A significant portion of this commerce occurred in the lower two miles of the Lower Passaic River, which is located downriver of the Pilot Study Area.

2.6 CONTAMINANT HISTORY OF THE LOWER PASSAIC RIVER

During the past two centuries, the Lower Passaic River has been subject to multiple influences and changes due to natural hydrological, topographical, climatological, and ecological conditions. However, changes due to rapidly expanding urban and industrial development in the region had a greater impact on the river. A full discussion of the conceptual site model for the Lower Passaic River will be provided in the *Focused Feasibility Study for the Lower Eight Miles of the Lower Passaic River* (The Louis Berger Group, Inc., anticipated December 2012). This feasibility study will also provide currently identified contaminants of potential concern.

Available information indicates that historical pollutant loadings throughout the 1900s have had a substantial impact on the ecological conditions of the Lower Passaic River as well as the Newark Bay estuary (McCormick and Quinn, 1975; Earll, 1887; Mytelka *et al*., 1981; Esser, 1982; Squires, 1981; Hurley, 1992). Degradation of water quality in the Lower Passaic River first became apparent during the Civil War (Brydon, 1974; Cunningham, 1966b). In 1873, coal tar residues suspended in the river water were noted (Brydon, 1974). The deteriorating water quality of the Lower Passaic River during this period forced many residents to dig their own wells; by 1885 however, a survey showed that seventy-five percent of groundwater wells also were polluted (Cunningham, 1966b).

Between 1884 and 1890, over 1,000 of the more than 1,500 wells in Newark had been closed due to contamination (Galishoff, 1988). In 1887, an inspector for the Passaic River declared that legal action would be required to mitigate pollution of the river from industrial waste practices (Brydon, 1974).

The growing population of Newark during the first half of the twentieth century resulted in the generation of increasing volumes of human wastes, resulting in a characterization of the Lower Passaic River as an open sewer (Suszkowski, *et al.* 1990). Efforts to improve water quality and to reduce the spread of disease in the Lower Passaic River led to the construction of a trunk sewer line system in 1924 (Brydon, 1974). However, despite the development of sewage treatment plants, many industrial facilities located along the Lower Passaic River were not connected to the regional treatment facility trunk line run by the Passaic Valley Sewerage Commissioners (PVSC) until the late 1950s (Brydon, 1974).

During the 1980s and early 1990s, several investigations were conducted to evaluate the concentrations of various potential contaminants in sediments in the Lower Passaic River. These studies include investigations conducted as part of the remedial investigation work at the Diamond Alkali Superfund Site, investigations conducted on behalf of Occidental Chemical Corporation (OCC) in the early 1990s, and investigations conducted by various governmental agencies, including USEPA, NOAA, and USFWS. These investigations indicated that sediments of the Lower Passaic River contain elevated concentrations of numerous hazardous substances including, but not limited to, cadmium, copper, lead, mercury, polycyclic aromatic hydrocarbon (PAH) compounds, polychlorinated biphenyl (PCB) compounds, polychlorodibenzodioxin/furan (PCDD/F) compounds, 4,4'-dichloro-diphenyl-trichloro-ethane (DDT), total petroleum hydrocarbons (TPH), and chlorinated herbicides and phenols.

3.0 PREPARATION AND DESIGN OF PILOT STUDY

The partner agencies conducted an extensive data collection effort in preparation for the Pilot Study. Studies included: an environmental dredging technology review; geophysical surveys (*i.e.*, bathymetric surveys, a side-scan sonar survey, magnetometry and gradiometry surveys, and sub-bottom profiler survey) as well as sediment coring to characterize chemical and geotechnical properties of the sediment. Other studies included a hydrodynamic study and predictive plume modeling. Together, the data collected from these preparatory programs were used to design the Pilot Study.

3.1 PILOT STUDY LOCATION

3.1.1 PILOT STUDY AREA DEFINITION

For the purposes of this document, the "Pilot Study Area" refers to the bank-to-bank area between RM2.6 and RM3.0 where all dredging operations occurred and data were collected (Figure 3-1). The Pilot Study Area is located within a larger geographical area defined by the federal navigational channel as the Harrison Reach, which extends from the Point-No-Point Conrail Bridge (RM2.2) to the Jackson Street Bridge (RM4.4). Sediments were dredged from the "Pilot Study Dredge Area."[1] Around the Pilot Study Dredge Area, geophysical surveys were conducted bank-to-bank in an area referred to as the "Pilot Study Survey Area." These features are presented in Figure 3-2 along with the positioning of the moorings that were part of the hydrodynamic monitoring program (refer to Section 6.1).

3.1.2 SITE SELECTION

The site for the Pilot Study was selected based on the river's geomorphology and site access (Figure 3-1). Between RM2.6 and RM3.0, the Lower Passaic River is aligned in a nearly true east-west direction. The river exhibits a series of bends upriver and

[1] On the NJDOT contract drawings, the Pilot Study Dredge Area is denoted as the "limits of targeted sediments" (NJDOT, 2005).

downriver of this area. Conducting the dredging in this relatively straight section reduced the complexity of estimating and evaluating water quality impacts because of reduced lateral mixing.

Moreover, the area between RM2.6 and RM3.0 was anticipated to provide sufficient air and water drafts (based on authorized federal navigational channel dimensions) to enable access with the selected dredging equipment and the associated tugboats and barges. In particular, 10 feet MLW was required for hopper barges and tugboat access. Actual water depths in the Pilot Study Area were confirmed with bathymetric surveys (conducted in March 2004 and November 2004), which reported depths ranging from 12.8 feet MLW at the downriver end to 11.8 feet MLW at the upriver end (TAMS/ET and Malcolm Pirnie, Inc., 2005b).

Project equipment was required to navigate under a series of bridges to access the site from Newark Bay. Table 2-1 lists the potentially affected bridges, starting from the Garden State Parkway Bridge across the Raritan River (near the decontamination demonstration site) to the Northeast Corridor Bridge (operated by Amtrak) that crosses the Lower Passaic River. Photographs of the Point-No-Point Conrail Bridge (RM2.3), New Jersey Turnpike Bridge (RM2.4), and Jackson Street Bridge (RM4.4) are presented in Figure 3-3a and Figure 3-3b. The bridge opening notification periods required by 33 Code of Federal Regulations (CFR) Part 117 are also presented in Table 2-1.

Other factors that impacted site selection included:

- <u>Contaminated sediment</u>: The site contains sediments with a geotechnical and chemical composition (as observed in the July 2004 coring program) that could allow for a reasonable assessment of available decontamination technologies and measurement of suspended solids released during dredging activities. However, these targeted sediment concentrations (top 3 feet) were not elevated to a level that would create major handling problems or unnecessarily increase risk from sediment resuspension. Therefore, shallower sediments were targeted for removal since minimizing risk during the Pilot Study (without engineering controls) was important to the partner agencies and stakeholders.

- River currents: High river velocities can make equipment anchoring and maneuvering more challenging. Given the tight time constraints of the Pilot Study, there was little opportunity to acclimate the dredging crew to operating conditions and a straightforward situation was desirable. Expected velocities at the site were not anticipated to pose difficulties for the Pilot Study.
- River Traffic: The site has relatively light river traffic, thereby enabling dredging work to proceed largely unimpeded.

3.1.3 Shoreline Features in Pilot Study Area

Both shorelines of the Pilot Study Area are almost completely developed, consisting of commercial and industrial properties. Figure 3-4 shows the northern shoreline just west of the New Jersey Turnpike Bridge. Gravel riprap and wooden or stone bulkheads border the train tracks along the northern shoreline. Figures 3-5a through 3-5e show the southern shoreline features from the New Jersey Turnpike Bridge (RM2.4) to the Diamond Alkali Superfund site (RM3.2). The southern shoreline also contains wooden bulkheads bordering several chemical facilities (both active and inactive) to the south of the Pilot Study Area, and an abandoned marina at Blanchard Street between the abandoned Commercial Solvents site and the Benjamin Moore facility.

3.2 DREDGING TECHNOLOGY REVIEW

An assessment of various dredging technologies was conducted to identify technologies that were potentially applicable to remediating contaminated sediments within the Lower Passaic River (TAMS/ET and Malcolm Pirnie, Inc., 2004a). This assessment concluded that for the Pilot Study, mechanical dredging systems had several advantages over hydraulic dredging systems. For example, mechanical dredging entrains less water, which makes this technology more suitable for subsequent thermal treatment. Water storage treatment and the designed scale of work were the major reasons why mechanical dredging was selected. For the size of the Pilot Study, it was not considered cost effective to mobilize the sediment slurry associated with hydraulic dredging. Other benefits of mechanical dredging systems included:

- Minimal capital investment in infrastructure and land for dewatering and treatment systems.
- Reduction in sediment transport and handling requirements related to delivering dredged material to sediment decontamination facilities that are beyond reasonable pumping distances from the Pilot Study Dredge Area.
- Simple overall logistical requirements for mobilization and operation and lower risk of operational failure or breakdown (fewer component systems).
- Better control in the context of a targeted, shallow dredging operation.
- Better ability to deal with debris, rocky material, and consolidated sediments.

The advantages highlighted above supported the use of mechanical dredging to achieve the objectives of the Pilot Study, which are specific to the dredging technology and site examined. Future design and implementation of a remedy for the Lower Passaic River will consider a full range of potential technologies, including hydraulic dredging and mechanical dredging, to determine the most appropriate alternative for the Lower Passaic River.

3.3 HYDRODYNAMIC STUDIES TO SUPPORT THE PILOT STUDY

Hydrodynamic studies were conducted by the Institute of Marine and Coastal Sciences at Rutgers University and the Water Resources Division of the United States Geologic Survey (USGS) for NJDOT from July 2004 through July 2005 (Chant and Wilson, 2004). These studies were conducted to prepare the hydrodynamic model (TAMS/ET, 2005); to predict and estimate the amount of sediment leaving the Pilot Study Area during dredging; and to aid in the design of the water quality monitoring program (refer to Section 6.2). In addition, the data collected during these surveys were utilized for the overall effort to model how sediments and contaminants move throughout the Lower Passaic River. The 2004-2005 hydrodynamic data collected by Rutgers University and USGS is available at the following webpage: http://marine.rutgers.edu/cool/passaic/.

3.4 GEOPHYSICAL SURVEYS TO SUPPORT THE PILOT STUDY

Geophysical surveys within the Pilot Study Survey Area, included: a bathymetric survey, side-scan sonar survey, sub-bottom profiler survey, magnetometer survey, and gradiometer survey. The detailed results of these surveys are included in Appendices B1 and B2 of the *Final Data Summary and Evaluation Report* (TAMS/ET and Malcolm Pirnie, Inc., 2005b).

3.4.1 Bathymetric Survey

In March 2004, a single-beam bathymetric survey (Innerspace Model 455) was performed in the Pilot Study Survey Area using 25-foot wide lanes. A second single-beam bathymetric survey was conducted on the area in November 2004 by USACE. Bathymetric profiles of the river bottom within the Pilot Study Survey Area were generated from the March 2004 and November 2004 surveys and were compared with previous surveys conducted by Tierra Solutions, Inc. (TSI) [refer to Figures 3-2 through 3-12 in the *Final Data Summary and Evaluation Report* (TAMS/ET and Malcolm Pirnie, Inc., 2005b)]. The data indicated that the deepest portion of the channel is closer to the northern bank of the river. From this location, the sediment surface slopes more gently upward towards the southern shoreline. The bathymetric surveys were used as part of the design to estimate sediment removal volumes for the Pilot Study.

3.4.2 Side-Scan Sonar Survey

In March 2004, a side-scan sonar survey was conducted in the Pilot Study Survey Area. The side-scan sonar survey was performed by running lines parallel to the shoreline with 50-foot spacing. A mosaic of the riverbed in the Pilot Study Survey Area was created from the side-scan sonar images. As part of the side-scan sonar survey, confirmatory surface sediment samples were collected and characterized in the field by an experienced field geologist using the Unified Soil Classification System (USCS). The results were used to verify the sediment types associated with side-scan sonar images.

The side-scan sonar survey identified three distinct bottom areas of interest and seven targets within the Pilot Study Survey Area (Figure 3-6; TAMS/ET and Malcolm Pirnie, Inc., 2005b). These results were considered during the design, and the proposed Pilot Study Dredge Area was positioned between these targets to avoid impacts on the dredging operation. A brief summary of the areas of interest include:

- Area 1 is a 20-foot wide strip spanning the entire length of the surveyed area along the north bank of the river; it was noted to contain debris including tires, rocks, poles, and other objects.
- Area 2 is a 100-foot wide strip 100 feet out from the wall along the north side of the surveyed area and spanning the entire length of the surveyed area; it was characterized by a series of parallel lines in the sediment. These lines may represent shallow ridges caused by barges scraping the bottom or dragging ropes or chains while transiting the area.
- Area 3 lies in the southwest portion of the survey area and consists of scattered debris over an approximately 30-foot wide strip extending 500 feet east from the western edge of the survey area about 90 feet out from the southern shoreline.
- Target 1 is a 15-foot tree trunk projecting three feet into the water column.
- Target 2 is an approximately 26-foot long piling resting on the river bottom surface.
- Target 3 is an approximately 37-foot long piling resting on the river bottom surface.
- Target 4 is an approximately 1,420-square foot area of probable differential bottom composition that is likely organic debris.
- Target 5 is a propeller mark extending approximately 78 feet to the southwest.
- Target 6 is an approximately 250- square foot area of probable differential bottom composition that is likely to be organic debris.
- Target 7 is a probable propeller mark extending approximately 36 feet to the southeast.

3.4.3 SUB-BOTTOM PROFILER AND MAGNETOMETER SURVEYS

Following the completion of the bathymetric and side-scan sonar surveys in March 2004, sub-bottom profiler and magnetometer surveys were performed in November 2004 (Figure 3-6). These surveys were conducted to characterize sediment, to detect buried ferrous and non-ferrous objects not detected in the side-scan sonar survey, and to aid in the interpretation of the side-scan sonar results. These surveys also provided information on debris (*e.g.*, the relative size and position of buried objects) as well as archaeological data (potentially significant historical submerged cultural resources) for compliance with the National Historic Preservation Act and the Abandoned Shipwreck Act.

The sediments that were characterized by the sub-bottom profiler survey were categorized by location. In shallow water, the sediments were very soft at the sediment-water interface. On the slopes, the sediments were mainly composed of gassy-silts and clays that were rich in organic matter. In the channel, the sediments were composed of well-consolidated silt and clay but still contained gas bubbles.

The magnetometer survey identified 12 distinct magnetic anomalies located within the Pilot Study Survey Area (Figure 3-6). Of the 12 targets identified in the magnetometer survey, only two could be correlated with the reflections in the sub-bottom profiles. In addition, two potential targets not detected in the magnetometer survey, were imaged by the sub-bottom chirp system. None of the targets were found to have a signature indicative of historically sensitive cultural resources. However, these surveys were not sufficiently resolved (due to geological background noise) to determine whether the targets identified would pose a hazard to the Pilot Study. These surveys and targets are described further in Appendix B2 of the *Final Data Summary and Evaluation Report* (TAMS/ET and Malcolm Pirnie, Inc., 2005b).

3.4.4 GRADIOMETER SURVEY

Following the magnetometer survey, Aqua Survey, Inc. recommended further investigation of the sediments in the Pilot Study Survey Area using a gradiometer to minimize the effects of geological interference encountered by the magnetometer survey. A gradiometer survey was authorized by NJDOT and conducted during the week of May 2, 2005. Results from this gradiometer survey did not identify any targets that would potentially interfere with the proposed Pilot Study dredging activities.

3.5 CORE COLLECTION AND ANALYSIS

A sediment coring program was conducted in July 2004 around the Pilot Study Dredge Area to characterize the sediments (TAMS/ET and Malcolm Pirnie, Inc., 2004b).[2] In brief, cores with adequate recovery were collected from 15 locations, forming a grid around the Pilot Study Dredge Area (Figure 3-7). Cores were transferred intact to the processing facility aboard the *R/V Robert E. Hayes* where cores were sliced into 1-foot sections (0-1, 1-2, 2-3, and 3-4 feet, respectively) and weighed (for bulk density determinations). Sediment sections were homogenized, subsampled, and shipped to the following laboratories: Mitkem Corporation in Warwick, Rhode Island [procured through the USEPA Contract Laboratory Program (CLP)]; USEPA Region 2 Division of Environmental Science and Assessment (DESA)[3] Laboratory in Edison, New Jersey; and Severn Trent Laboratories in Burlington, Vermont (STL-VT) and Knoxville, Tennessee (STL-TN). Analytical data from the July 2004 sampling event that were generated by non-USEPA laboratories (*i.e.*, STL-VT and STL-TN) were not validated while analytical data from USEPA laboratories (*i.e.*, Mitkem Corporation and USEPA Region 2 DESA Laboratory) were validated.

According to the sediment coring program (TAMS/ET and Malcolm Pirnie, Inc., 2004b), a total of 45 discrete samples (plus quality assurance/quality control samples) were collected. One sediment core was collected from each of the 15 grid locations and one sediment sample was generated for each of the three 1-foot intervals (between 0 foot and 3 feet) in the core. Samples were identified by grid location and depth interval; for example, the top sample taken from the core in grid cell A1 was designated A101 while

[2] Accuracy on the July 2004 coring program includes: ±5 feet for depth of water, ±3 feet for horizontal positioning, ±2.5 centimeters for sediment penetration depth, and ±1 centimeter for sediment depth in the core.

[3] DESA is accredited under the National Environmental Laboratory Accreditation Conference (NELAC), a voluntary association of state and federal agencies. NELAC established and promoted a national accreditation program that provides a uniform set of standards for the generation of environmental data that are of known and defensible quality. The laboratory tests that are accredited have met all the requirements established under the NELAC Standards.

the sample from the 2-3 foot interval taken from the core in grid cell E3 was designated E323, and so forth. In addition to the samples required, one additional sample from the 3-4 foot interval was also collected at each grid location to examine the surface to be left behind by the dredging operation.

The 3-4 foot interval samples were shipped to STL-VT but were 'archived' – stored frozen at the laboratory – pending further instructions regarding compositing and analysis. In late October 2004, the project team decided to analyze the archived samples. STL-VT prepared and shipped the archived samples to the respective laboratories performing the analyses. Due to the limited sediment volumes available for the archived samples, the archived samples were determined for either chemical analyses or geotechnical analyses. The selected analyses were obtained from alternating coring grid locations in a checkerboard pattern (starting with A134, then A334, B234, *etc.*) for chemical analysis for a total of eight archived samples while the seven remaining archived samples (starting with A234, then B134, B334, *etc.*) were submitted for geotechnical analyses.

In addition to these discrete samples, composite samples were also generated by combining material from cores in rows perpendicular to shore for each depth interval from 0-4 feet (*e.g.*, A01C is a composite of A101, A201, and A301). In this manner, a total of 20 "row composites" were generated (*i.e.*, five rows from each of the four depth intervals).

The sediment core samples were analyzed for volatile organic compounds (VOC), semivolatile organic compounds (SVOC), PCB congeners and PCB Aroclors, herbicides, PCDD/F congeners, metals, total organic carbon (TOC), and geotechnical parameters. A full discussion of the data obtained from the sediment coring program is presented in the *Final Data Summary and Evaluation Report* (TAMS/ET and Malcolm Pirnie, Inc., 2005b). The data are discussed below and presented in Figure 3-8 through Figure 3-15 (tabulated data are available in Table 3-1). Historical data from RM2.7 to RM4.1 in the vicinity of the Pilot Study Area are shown in Figure 3-16 through Figure 3-22 showing the historical contaminant distribution in the upper four feet of sediments.

As part of the July 2004 sampling event, one bulk sample (a 60 gallon drum designated as T-17) was obtained by USEPA personnel for preliminary treatability studies by sediment decontamination technology vendors (BioGenesis and Minergy). The bulk sample was obtained from excess material collected for surface grabs (roughly the top six inches of sediment) using a petite ponar dredge sampler. Other vertical and horizontal composites were generated from excess sediment, and custody was transferred to personnel from academic institutions and other agencies.

3.5.1 VOC

VOC data were only generated for the samples from the 0-3 foot intervals (the archived samples were not analyzed for VOC compounds). VOC compounds were detected in only 12 of the 48 discrete samples (including duplicates). Detected VOC concentrations ranged from less than 12 micrograms per kilogram of sediment (μg/kg) to non-detected concentrations. Chlorobenzene was the most frequently detected VOC, reported in eight samples at a maximum concentration of 12 μg/kg. VOC data were validated by USEPA.

3.5.2 SVOC

The discrete samples from the 0-3 foot interval were analyzed by DESA for the CLP target compound list (TCL) SVOC analytes. Eight archive samples from the 3-4 foot interval were analyzed for 24 PAH compounds (not the CLP SVOC TCL) by DESA. SVOC compounds (other than phthalates) and 17 of the 24 target PAH compounds were generally not detected. Total PAH concentrations are typically lowest in the near-surface (0-1 foot interval) samples (with PAH compounds detected in only four of the 15 discrete samples from this interval) with the highest concentrations and the highest frequency of detection (14 of 15 samples) in the 2-3 foot interval. While PAH compounds were detected in all eight of the 3-4 foot interval cores, concentrations reported were generally lower than those in the 2-3 foot core sections analyzed earlier by DESA. SVOC data were validated by USEPA. The Total PAH concentrations are shown in Figure 3-8 by grid cell and depth interval.

3.5.3 PESTICIDES

Pesticide data were generated for the 0-3 foot interval samples by Mitkem Corporation, and eight archived 3-4 foot interval samples were analyzed for pesticides by DESA. DDT and related compounds [4,4'-dichloro-diphenyl-dichloro-ethane (DDD) and 4,4'-dichloro-diphenyl-dichloro-ethylene (DDE)] were detected in all the samples analyzed by both Mitkem Corporation and DESA laboratories. For the shallower samples (0-3 feet), DDD, DDE, and DDT were detected in at least 80 percent of the valid sample results. Total DDT ranged from 50 µg/kg to 1,100 µg/kg;[4] in some cases, the total may be biased low due to rejection of one (or in one sample, two) of the three analytes.[5] Conversely, DDD and DDE were detected in all of the 3-4 foot interval samples while DDT was detected in none of the samples. The Total DDT concentrations in the 3-4 foot interval samples ranged from 30 to 48 µg/kg, which were lower than the Total DDT concentrations reported for the shallower samples. Pesticide data were validated by USEPA. The Total DDT concentrations are shown in Figure 3-9 by grid cell and depth interval.

3.5.4 PCB AROCLORS

PCB Aroclor data were generated for the 0-3 foot interval samples by the Mitkem Corporation while the archived 3-4 foot interval samples were analyzed by the DESA laboratory. In addition, STL-TN analyzed 20 row composites for PCB Aroclors (five rows from each of the four depth intervals from 0-4 feet). The Mitkem Corporation and DESA data (discrete samples) were validated, but the STL-TN data (composite samples) from the July 2004 sampling event were not validated.

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[4] Total DDT refers to the sum of valid detections of DDD, DDE, and DDT from the 4,4'-isomer series to be consistent with the historical Total DDT definition.

[5] In Lower Passaic River sediments, matrix interferences due to the presence of sulfur commonly interfere with the quantification of DDT, DDD, and DDE and their laboratory surrogates.

The PCB Aroclor results for the discrete and composite samples varied both in the magnitudes of the detections and the Aroclors identified, indicating that the PCB Aroclor mixture was not uniform with depth. PCB Aroclors were detected in 30 of the 48 discrete samples (45 environmental samples plus three field duplicates). In samples where PCB Aroclors were detected, the Total PCB (Aroclor) concentrations range from 230 µg/kg to 5,100 µg/kg. Aroclor 1254 was the PCB mixture most often reported (in 28 samples) with less frequent detections of Aroclor 1242 (10 samples) and Aroclor 1260 (one sample). Aroclor 1248 was the only Aroclor reported for the eight archived 3-4 foot interval samples with detections ranging from 380 to 780 µg/kg.

Total PCB (Aroclor) detections were higher for the 0-3 foot row composites, ranging from 1,200 µg/kg to 7,400 µg/kg. Aroclors 1248 and 1254 were reported in all of these composite samples. For the five row composites from the same depth interval, Total PCB (Aroclor) concentrations were reportedly higher than the corresponding concentrations reported in the discrete samples, typically by more than an order of magnitude. Currently, there is no explanation for these differences. The Total PCB (Aroclor) concentrations are shown in Figure 3-10 by grid cell and depth interval.

3.5.5 PCB Congeners

STL-TN also analyzed 20 row composites for PCB congeners (five rows from each of the four depth intervals from 0-4 feet). For comparability, each of these row composites was also analyzed for PCB Aroclors. The vendor bulk sample was also analyzed for PCB congeners. Overall, the average Total PCB (congener) concentration was greater than the average Total PCB (Aroclor) concentration by about 7 percent. The median Total PCB (congener) concentration was greater than the median Total PCB (Aroclor) concentration by less than 3 percent. At each location, a paired t-test was run on Total PCB (congener) concentration and Total PCB (Aroclor) concentrations. The resulting p-value of 0.16 was considered statistically significant; consequently, the overall comparability of two Total PCB values was viable. PCB congener data from the July 2004 sampling event were not validated. The Total PCB (congener) concentrations are shown in Figure 3-11 by grid row and depth interval.

3.5.6 HERBICIDES

STL-VT performed the herbicide analysis on the 45 discrete core samples from the 0-3 foot intervals and on eight archived samples from the 3-4 foot interval. Only 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) were target analytes. These herbicides were not frequently detected in the sediment samples. 2,4-D was detected in four samples (plus one duplicate) at concentrations ranging from 260 μg/kg to 750 μg/kg while 2,4,5-T was detected in three samples at concentrations ranging from 40 μg/kg to 67 μg/kg. No herbicides were detected in any of the 3-4 foot interval samples or 0-1 foot interval samples. The herbicide data from the July 2004 sampling event were not validated.

3.5.7 PCDD/PCDF

STL-TN conducted analysis of PCDD/F on the same 20 row composite samples that were analyzed for PCB congeners, plus one field duplicate, and the vendor bulk sample. Total tetrachlorodibenzodioxin (Total TCDD) and 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) were detected in all samples analyzed. These data show a general trend of increasing concentration with depth, although there are exceptions evidenced in particular rows. The PCDD/F data from the July 2004 sampling event were not validated. The Total TCDD concentrations are shown in Figure 3-12 by grid row and depth interval.

3.5.8 METALS

Analysis for the 23 target analyte list (TAL) metals was conducted on all 45 of the discrete samples from 0-3 feet and the eight archived (3-4 feet) samples by the DESA laboratory. DESA data are subject to internal review prior to release; as such, and as indicated in the cover letter accompanying the data, these data are considered USEPA-validated and fully usable as reported. Mercury was detected in every sample analyzed, at concentrations ranging from 1.4 to 12 milligrams per kilogram of sediment (mg/kg). Lead was also detected in every sample analyzed, at concentrations ranging from 210 to 1,100 mg/kg. Metals data were validated by the USEPA. For both mercury and lead, there is a general trend of increasing concentration with depth, as shown in Figure 3-13 and Figure 3-14, respectively.

3.5.9 Total Organic Carbon

TOC analysis was performed on all 45 of the discrete samples from 0-3 feet and eight archive (3-4 feet) samples by the DESA laboratory. TOC values reported range from 45,000 mg/kg (4.5 percent) to 81,000 mg/kg (8.1 percent). There was no discernible trend of TOC concentration with depth. TOC data were validated by the USEPA.

3.5.10 Geotechnical Data

Geotechnical analyses included percent solids, moisture content, Atterberg limits (liquid limit, plastic limit, and plasticity index), specific gravity, and grain size performed in the laboratory. The bulk density analysis was performed in the field. Geotechnical analyses were conducted on 44 of the 45 discrete samples from the 0-3 foot interval. (Note that there was insufficient recovery/volume for sample E201.) The grain size analysis was performed on archived 3-4 foot interval samples.

Percent solids and moisture content [American Society for Testing and Materials (ASTM) D2216] data are in good agreement, after accounting for the different data reporting conventions of the two methods. These data show the expected trend of increased solids content with depth. The average solids content is 37 percent in the 0-1 foot interval, 43 percent in the 1-2 foot interval, and 48 percent in the 2-3 foot interval. Solids results reported by different laboratories on the samples from the same interval are in good agreement, generally agreeing to within ±4 percent.

Atterberg results were reported for liquid limit, plastic limit, and plasticity index. Reported liquid limit values ranged from 50 to 116 with an average liquid limit of 71.2 and a median of 66. Plastic limits results range from 34 to 56 with an average of 44.2 and a median of 43. Plasticity index results range from 11 to 63 with an average of 27.3 and median of 24 for the 43 discrete samples for which data were reported. Specific gravity analyses were performed by ASTM D854. Specific gravity values (density of dry solids) ranged from 2.06 to 2.56 with an average of 2.35 and a median of 2.34.

Grain size data are shown on Figure 3-15 as a cross-section of the sediment cores. Silt is the predominant grain size fraction, typically representing 70 to 80 percent of the sample. Silt is the dominant fraction in all but one of the samples analyzed. The sand fraction was highly variable, ranging from 5 percent to a maximum of 50 percent. The clay fraction was generally low with a maximum value of less than 10 percent.

3.6 DESIGN OF PILOT STUDY

3.6.1 FEATURES OF DESIGN

The Pilot Study was designed to yield information on dredging performance associated with production environmental dredging, operating with one mechanical dredge system. No construction work occurred during the Pilot Study, and dredging was conducted without any containment barriers to monitor potential resuspension associated with the dredging operations [as described in the planning documents (TAMS/ET and Malcolm Pirnie, Inc., 2005a)]. The Pilot Study did not include clean-up passes or the collection of sediment residual samples. Data collected during the July 2004 coring program were used to assess the level of contamination that would be in the post-dredge surface.

The proposed Pilot Study Dredge Area was designed to represent a grid aligned orthogonally with the river bottom contours (1.1 acres)[6]. The grid was further divided into three rows of five cells. The width of each cell was designed to capture about a 3-foot drop in river bottom elevation. By following the river bottom contours, the dredging operation minimized overall cut depths and constrained the dredging depth to the portion of the sediment characterized by the July 2004 sediment coring program. Consequently, dredged material was assumed to have similar geotechnical characteristics (70-80 percent silt with a total organic carbon content ranging from 5-8 percent) and contaminant levels as those samples collected during the July 2004 sediment coring program.

[6] The actual Pilot Study Dredge Area is 1.2 acres.

As part of the Pilot Study design, dredging operations would be conducted using an 8-cubic yard environmental clamshell bucket. This relatively small size bucket was selected to satisfy two objectives of the Pilot Study. First, dredging operations were expected to extend over a 5-work day period to accommodate the monitoring programs. By using a smaller bucket, the anticipated productivity would satisfy the targeted removal rate of 1,000 cubic yards within a 12-hour period. Second, a shallow depth (maximum depth of 3 feet relative to sediment surface) was targeted in the Pilot Study Area to avoid dredging and exposing highly contaminated sediments that were present at deeper depths. According to the *NJDOT Plans and Specifications for Environmental Dredging in the Lower Passaic River* (NJDOT, 2005), penalties that included the placement of cap material would be imposed if the deeper contaminated sediments were exposed. Consequently, a smaller bucket would allow for more vertical control on the dredging operations.

The Pilot Study Dredge Area was positioned between the debris that was identified during the geophysical surveys to minimize potential impacts to the dredging operation (Figure 3-6). However, despite efforts to avoid all the identified debris, one side-scan sonar target and two magnetometer targets were located within the proposed boundaries of the Pilot Study Dredge Area. The side-scan sonar target (Target 4) was identified as organic debris and considered unlikely to impact dredging operations, and the magnetometer targets were not sufficiently resolved to determine whether they would pose a hazard to the dredging operation.

3.6.2 MODIFICATIONS TO THE DESIGN

Approximately 5,000 cubic yards of contaminated sediments were originally targeted for removal during the Pilot Study (Figure 3-2). This targeted volume and associated design plans and cut lines are based on the March 2004 single-beam bathymetric survey (TAMS/ET and Malcolm Pirnie, Inc., 2005a). However, this targeted volume was scaled-back to 4,700 cubic yards to accommodate restrictions on the volume of material that the decontamination technology could handle and to account for sediments that may have accumulated in the dredging area in the time between the design (March 2004) and execution of the work (December 2005).

A pre-dredge survey, which was conducted by Rogers Surveying, Inc. on November 28, 2005 (approximately one week prior to dredging), indicated that there was approximately 4,300 cubic yards of material in the targeted dredge prism. This difference in volume between the March 2004 and November 2005 surveys is conceivably a result of scour [significant storm events occurred in the spring and fall of 2005 with river flows over 12,000 cubic feet per second (ft^3/s)]. However, the discrepancy could also possibly be the result of differing surveying techniques: the March 2004 survey was performed using single beam techniques while the November 2005 survey was performed using multi-beam techniques. The 400 cubic yards volume difference between the March 2004 and November 2005 surveys represents an average of 2 inches over the dredging area. While the instrumentation used for the single-beam survey and multi-beam survey have approximately the same accuracy for each datum, the multi-beam survey collects more bathymetric data than the single-beam, thus reducing the overall uncertainty of the survey and resolving the sediment bed elevation.

In addition, the Pilot Study was originally planned to be implemented during a period of neap tide and low river discharge, which normally occurs in August (TAMS/ET, 2005), to distinguish the solids resuspended by the dredging operations from naturally occurring background conditions. However, the Pilot Study was postponed to December 2005 due to several factors, including (1) heavy rains that were associated with the remnants of a tropical storm, which created flood conditions on the Lower Passaic River, (2) construction delays at the sediment off-loading facility and arrival of the storage system, (3) and the procurement process. While waiting for more favorable weather conditions would have assisted in the monitoring programs, the Pilot Study needed to proceed as soon as the offloading facility was completed. The decontamination vendors, who were participating in the WRDA/NJDOT decontamination demonstration, were not available after December 2005.

4.0 DREDGING OPERATION

The following section describes the dredging operations and other field procedures implemented during the Pilot Study. Work was conducted in accordance with approved project plans (TAMS/ET and Malcolm Pirnie, Inc., 2005a), including the Work Plan, QAPP, and HASP. (These plans and additional documents can be found on the public website www.ourpassaic.org.) Dredging operations are specific to production environmental dredging, operating with one mechanical dredge system.

4.1 DREDGING OVERVIEW

Dredging operations were performed by Jay Cashman, Inc. (Quincy, Massachusetts) with support from their subcontractor, Cable Arm, Inc. (Trenton, Michigan) from December 5, 2005 through December 10, 2005. Records from the dredging operation are available in the *Final Completion Report* (Jay Cashman, Inc., 2005a; Appendix A). Relevant photographs depicting dredging operation and associated monitoring are presented in Figure 4-1. Dredging operations were conducted pursuant to *NJDOT Plans and Specifications for Environmental Dredging in the Lower Passaic River* (NJDOT, 2005) and the dredger's work plan (Jay Cashman, Inc., 2005b).[7]

Dredging removed 4,000 ±200 cubic yards of contaminated sediment from the Pilot Study Dredging Area (1.2 acres; approximate dimensions of 170 feet wide by 290 feet long) to elevations of 11 feet MLW, 13 feet MLW, and 15 feet MLW. The 13-foot cut was dredged on December 5, 2005, the 11-foot cut was dredged on December 6, 2005, and the 15-foot cut was dredged on December 7-8, 2005 and December 10, 2005. The duration of dredging for the 15-foot MLW cut was spread over three days in order to allow the resuspension monitoring to occur over several ebb and flood tides. Note that no

[7] Full plans and specifications were developed by the project team technical experts for use in NJDOT's procurement process (NJDOT, 2005). The contract was awarded to Jay Cashman, Inc. based on cost and qualifications (refer to Appendix B for the Jay Cashman, Inc. project and staff references that were submitted as part of their proposal to NJDOT).

dredging was performed on December 9, 2005 due to severe snowstorm and gale force winds. Dredging activities that were originally scheduled for December 9, 2005 were performed on December 10, 2005. Dredging operations were conducted without any containment barriers in order to monitor sediment resuspension.

4.2 MOBILIZATION

4.2.1 VESSEL AND EQUIPMENT SPECIFICATIONS

Nine vessels were involved in the dredging operations of the Pilot Study. These nine vessels were supplied and manned by Jay Cashman, Inc. Dredging equipment and support vessels were reviewed by the NJDOT and approved prior to the actual dredging operation. Table 4-1 provides vessel specifications. Additional supporting material is available in Appendix C, including equipment literature, operator manuals, and equipment photographs. All vessels met the 2-foot minimum hull clearance as pursuant the *NJDOT Plans and Specifications for Environmental Dredging in the Lower Passaic River* (NJDOT, 2005). Other vessels were present during the Pilot Study, but they were involved with the water quality or hydrodynamic monitoring programs and did not impact dredging operations.

Dredging was performed with the *Wood I*, a 250 horsepower vessel that was equipped with a 2400 Lima crane, a 100-foot boom, and a 8-cubic yard (19,000 pounds) environmental clamshell bucket (model SN05406; manufactured in 2005 by Cable Arm, Inc.). According to Cable Arm, Inc., the bucket was designed and patented to achieve level cuts with a ±3 inch performance feature (level-cut performance features were not verified on the Lower Passaic River). These level cuts are achieved by allowing the bucket sides to draw together while the pivot point lifts, which leaves a large rectangular footprint that is very close to level. Each successive dredge pass or 'bite' then overlaps the previous dredge 'bite' to ensure complete sediment removal. Pressure sensors mounted on the bucket were part of the Cable Arm, Inc. ClamVision® positioning system to detect bucket closure and estimate the depth of the dredge. According to Cable Arm, Inc., the depth pressure sensors had an accuracy of 0.001 percent of the vertical depth. The standard operating procedure for the environmental clamshell bucket and the operator manuals and the Cable Arm, Inc. ClamVision® positioning system are available in Appendix C.

Dredged material was contained in two hopper barges (or "scows"): *SEI 3000* and *SEI3003*, which have a 3,000 ton capacity. As a Best Management Practice, a rinse tank was on-site to remove loose sediments adhering to the bucket, prior to re-submerging the bucket in the river. A custom-welded rinse tank (dimensions of 18 feet long × 14 feet wide × 9 feet deep), which was designed to accommodate the 8-cubic yard environmental bucket, was positioned on a 90 foot × 30 foot barge. For part of the Pilot Study, dredging equipment was positioned in the field using a guide barge (*SEI 32* equipped with three 50-foot spuds) and several tugboats, including the *Dorothy* and *Vernick* (1,800 horsepower single screw tugboats), *Uncle George* (3,400 horsepower twin screw tugboat), and *Alex D* (500 horsepower twin screw tugboat). The *Alex D* also served as a crew boat and performed bathymetric surveys. However, vessel maneuvers were optimized as a Best Management Practice to minimize vessel related resuspension impacts.

4.2.2 POSITIONING

As part of the Pilot Study design, positioning of the dredge would be recorded using a real-time kinematic (RTK) global positioning system (GPS) unit. Accordingly, Cable Arm, Inc. installed a previously tested base station at the 80 Lister Avenue site in Newark, New Jersey on December 1, 2005 to provide an RTK signal to the GPS unit on the *Wood I*. An on-board system was intended to act as the back-up system, which included a Trimble AG132 GPS antenna and Hemisphere R100, which was associated with the ClamVision® navigational positioning system (WINOP Dredge Positioning System). However, due to access issues associated with the base station site and radio interference, the dredging contractor decided to use the back-up Trimble/ClamVision® system as the primary system to determine bucket positioning. GPS equipment literature is included in Appendix C.

This deviation from the Work Plan did not impact the evaluation of vertical accuracy of the bucket since the ClamVision® positioning system and associated depth pressure sensors provide compatible vertical data. The depth pressure sensors have a 0.001 percent vertical accuracy, so for the targeted depths of 11 feet MLW, the vertical accuracy of the depth pressure sensor is ±0.1 inches and at 15 feet MLW, the vertical accuracy of the depth pressure sensors is ±0.2 inches. These tolerances are compatible with the vertical accuracy of the proposed RTK GPS (model Trimble MS860) of ±0.1 inches. Moreover, the vertical accuracy of the depth pressure sensor satisfies the *NJDOT Plans and Specifications for Environmental Dredging in the Lower Passaic River* (NJDOT, 2005) for vertical tolerance ±6 inches.

The horizontal positioning of the bucket was effected by the equipment change but not significantly. The horizontal accuracy of the proposed RTK GPS (model MS860) was ±0.1 inches whereas the horizontal accuracy of the Trimble/ ClamVision® system was ±1 meter. However, since horizontal accuracy was not an objective of the Pilot Study and was not evaluated, the change in the positioning equipment was accepted. A record of horizontal positioning for the dredge as recorded by the ClamVision® software is provided in the *Final Completion Report* (Jay Cashman, Inc., 2005a; Appendix A). Calibration records for the positioning equipment are not available.

4.2.3 PERMITS

Permits acquired for the Pilot Study include a Revocable License and a Federal Consistency/Water Qualification Certification under the Clean Water Act. The Revocable License was issued by the NJDEP (Bureau of Tidelands Management) to the NJDOT on February 7, 2005. The Federal Consistency/Water Qualification Certification was issued by the NJDEP to USEPA on October 6, 2005. Although the NJDOT requested a Nationwide Permit 38 (Cleanup of Hazardous and Toxic Waste) from the USACE, the USACE deemed the permit unnecessary for the Pilot Study. This permit information was forwarded to the United States Coast Guard on September 26, 2005 in a notice to mariners.[8] Copies of letters and permits pertaining to the Pilot Study are included in Appendix D.

4.3 HEALTH AND SAFETY

4.3.1 SITE-SPECIFIC HEALTH AND SAFETY PLANS

Two HASPs specifically addressing the issues associated with the Pilot Study were prepared. One was submitted as an addendum to the Lower Passaic River Restoration Project HASP (TAMS/ET and Malcolm Pirnie, Inc., 2005a), covering the field team members (from TAMS/ET and Malcolm Pirnie, Inc.) that were performing monitoring and oversight activities. The other HASP was submitted by the dredging contractor covering the activities of Jay Cashman, Inc. personnel, Cable Arm, Inc. personnel, and support members such as Rogers Surveying, Inc, who performed the pre-dredge and post-dredge bathymetric surveys. Occupational Safety and Health Administration (OSHA) training requirements and task hazards are addressed in the HASP.

A kick-off meeting was held on October 12, 2005 for field team members, including a health and safety briefing led by the Site Health and Safety Manager. During this meeting, OSHA related Hazardous Waste Operations and Emergency Response (HAZWOPER) training materials for all team members were reviewed. Team members were then given copies of the HASP Addendum to review prior to the start of Pilot Study. Site-specific health and safety concerns of the project were discussed, and captains from the USACE, USFWS, and Aqua Survey, Inc. water quality monitoring vessels presented their requirements for field team members on their vessels. Discussions focused on on-water activities, detailing activities, and potential hazards including: tying off and transferring between vessels, pinch hazards, personal flotation devices (PFDs), drowning hazards, working near the dredge, radio and emergency communication between vessels, emergency procedures, use of survival gear, transporting personnel and samples, and rescue operations.

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[8] The December 5, 2005 start date for the Pilot Study was verbally communicated to the United States Coast Guard by NJDOT.

4.3.2 FIELD IMPLEMENTATION OF HEALTH AND SAFETY PLAN

On December 5, 2005, prior to the commencement of dredging activities for the Pilot Study, a site health and safety briefing was conducted for all members of the field team. Each participant was reminded of the appropriate safety requirements related to working on the vessels, including responsibility for co-worker safety, drowning hazards and PFDs, use of survival suits, and slip hazards. A representative of Jay Cashman, Inc. spoke about their operations and established safety protocols, especially regarding communication and emergency procedures. Vessel operators were cautioned from PVSC regarding the hazards of debris on the river. Finally, emergency telephone numbers and marine radio channels for communication among vessels, with the dredge, and with the United States Coast Guard rescue station were distributed to each boat crew.

The Site Health and Safety Manager boarded each vessel to confirm that the required United States Coast Guard safety equipment was aboard. Operational conditions, working area required for the captain, working room for the crew, equipment storage, active working areas, and sample storage were discussed. A review of each captain's understanding of the protocols in the event of an emergency, tying off, and transfer of personnel between vessels was reviewed.

Due to the extreme drop in temperature near the beginning of the work, all participants were reminded of the increased hazards associated with working in cold weather conditions. A detailed review of procedures in the event of a person falling overboard under these conditions was discussed with all of the captains by the Site Health and Safety Manager. Rock salt was provided to each boat crew since ice was starting to build up on the vessels in the morning. Rock salt was also used on the aluminum dock ramp, as needed. On December 9, 2005, extreme winter weather brought blinding snow, high winds, and poor visibility and it was determined that conditions were too hazardous to safely perform water quality monitoring activities. Consequently, dredging activities were postponed until the next work day when conditions were more favorable for water quality monitoring.

During the monitoring program, the Aqua Survey, Inc., Rutgers University, and USFWS water quality monitoring vessels encountered debris, which resulted in one damaged propeller, which required replacement. The Malcolm Pirnie, Inc. monitoring vessel snagged a submerged tarp on the last day; however no damage resulted, and the tarp was safely removed from the propeller. Monitoring vessels were more likely to encounter floatable debris than the dredging vessels since these monitoring vessels were sampling the water column along the shoreline and in the mudflats. The encountered debris was not photographed. None of these incidents resulted in any danger to the personnel aboard the vessels or impacted dredging operations. The monitoring vessels were able to return safely to the PVSC dock.

4.3.3 Effectiveness of Health and Safety Plan

The Pilot Study was conducted safely. Each of the crews performed their work following the safety instructions detailed in the HASPs and as addressed in the kick-off and site safety meetings. No reportable incidents occurred over the duration of the Pilot Study field activities.

Situations requiring minor adjustments to procedures did occur, mainly due to the cold, such as: personnel who were getting chilled were transported back to the *SUV Hudson* via the shuttle boat to warm-up and a replacement, if required, was shuttled back. Survival suits and different styles of water resistant gloves were made available to the crews performing different tasks. Hot food was delivered to the boat crews or a single hot lunch break was provided aboard the *SUV Hudson*.

4.4 DELAYS

Pilot Study experienced delays associated with mobilization and equipment repair. These delays are described below; impacts to dredging performance are described in Section 5.2.3.

4.4.1 BRIDGE DELAYS

On Friday, December 2, 2005, Jay Cashman, Inc. attempted to mobilize the dredge *Wood I* using the tugboat *Uncle George* from their yard in Staten Island to the Lower Passaic River. The dredging contractor was delayed at the Point-No-Point railroad bridge located east of the Pilot Study Area. Conrail attempted to raise the spans; however, the bridge malfunctioned before the dredge could be moved underneath. Conrail had made necessary reparations throughout the weekend, and the bridge was operational by Sunday, December 4, 2005. The dredge and associated equipment arrived at the Pilot Study Area early Sunday afternoon, and the Pilot Study began on schedule.

4.4.2 IMPROPER SETUP OF PRESSURE SENSOR EQUIPMENT

As a result of the bridge delay, the dredging contractor had insufficient time to properly set up the Cable Arm, Inc. ClamVision® depth pressure sensor prior to dredging activities on December 5, 2005. The improper installation resulted in problems with the sensor cables on December 5-6, 2005. Ultimately, the sensor cable jumped the sheave on December 6, 2005, and the system was disconnected to avoid damage. Delays associated with troubleshooting the depth sensor (repairs were completed during a scheduled work stoppage and barge change out) impacted dredging activities on December 5-6, 2005. Further delays were minimized by the presence of an experienced crane operator, who was capable of operating the environmental dredge bucket manually until the depth sensors could be properly repaired. Dredging operation continued by utilizing markings on the bucket chain to estimate bucket depth as traditionally used in navigational dredging operations. Note that vertical dredging accuracy was also impacted when the depth sensors were not operating properly. Beginning December 6, 2005 at 1735 hours Eastern Standard Time (EST) till the end of the Pilot Study, the depth sensors were functional and operating correctly.

4.4.3 DAMAGED DREDGING BUCKET

The Pilot Study Dredge Area was positioned between debris that was identified during the geophysical surveys to minimize potential impacts to the dredging operation (Figure 3-6). Despite efforts to avoid the identified debris, one side-scan sonar target and two magnetometer targets were located within the proposed boundaries of the Pilot Study Dredge Area. The side-scan sonar target (Target 4) was identified as organic debris and considered unlikely to impact dredging operations. The magnetometer targets were not sufficiently resolved to determine whether they would pose a hazard to the Pilot Study. As per the *NJDOT Plans and Specifications for Environmental Dredging in the Lower Passaic River* (NJDOT, 2005), the dredging contractor had the option to remove the identified debris; however, since the data suggested that the debris would not pose a threat to the dredging operation, the dredging contractor chose not to conduct debris removal operations.

Overall, the dredging operation was not impacted by debris,[9] except for activities on December 6, 2005 when metal debris damaged the dredge bucket gasket. This occurrence was not photographed. Since dredging operations on December 6, 2005 occurred in grid cell B3, C3, and D3 in the 11-foot cut, it is likely that the bucket encountered magnetometer target number 134022 or target number 131542 (refer to Figure 3-6). According to the *Final Data Summary and Evaluation Report* (TAMS/ET and Malcolm Pirnie, Inc., 2005b), these magnetometer targets are associated with single small diameter ferrous objects (approximately 18 to 20 linear feet), such as a coil of wire rope or chain.

Repairs to the bucket gasket were completed during a planned work stoppage and barge change out while the depth sensor equipment was repaired. By 1735 hours EST till the end of the Pilot Study, the bucket operated properly and no further damage was reported. Since repairs to the bucket were completed during a planned work stoppage, dredging performance was not impacted by the damaged bucket.

[9] During the water quality monitoring program, monitoring boats encountered debris; however, monitoring boats were more likely to encounter floatable debris since these boats were monitoring water quality along the shoreline and in the mudflats.

4.5 BEST MANAGEMENT PRACTICES

Dredging was conducted using techniques and equipment designed specifically to reduce sediment resuspension to the water column. To begin, the dredge was fitted with an environmental clamshell bucket, which was designed to expel excess water from the top and remove targeted sediments as close to *in-situ* densities as possible. Further, the bucket is designed to produce a flat sediment cut for better vertical control of the excavation. The jaws are also designed to close completely against a gasket to seal the bucket and reduce the potential for sediment resuspension. The bucket was outfitted with electronic sensors (Cable Arm, Inc. ClamVision®) and a GPS to monitor cycle time, location, and sediment removal.

A rinse tank was used to remove loose sediments adhering to the bucket between 'bites', prior to re-submerging the bucket in the river. Positioning of the rinse tank was also evaluated throughout the dredging program (*i.e.*, tugboat assisted versus stationary positioning). Initially, on December 5-6, 2005, the tugboat *Alex D* was used to move the rinse tank into position to minimize crane boom extension. However, the propeller wash (from the repositioning of the rinse tank barge) unnecessarily resuspended sediments. For the remainder of the Pilot Study, December 7-8, 2005 and December 10, 2005 (no dredging activities occurred on December 9, 2005 due to inclement weather), the rinse tank barge was secured in a fixed position on the port side of the dredging barge while still permitting easy access by the bucket operator. However, this stationary positioning impacted dredging performance by increasing overall cycle time.

Another Best Management Practice tested during the Pilot Study was the optimization of the bucket operation. During the operations that occurred on December 5-6, 2005, frequent overfilling of the bucket was observed because the depth pressure sensors were not operating properly. Dredge monitoring control instrumentation failures and a concern by the operator to meet the proposed removal yardage contributed to this overfill. During the December 7-8, 2005 and December 10, 2005, overfilled buckets were less frequent because the depth pressure sensors were operating properly. Dredging techniques and the cycle time between bucket grabs were then adjusted to optimize production (*i.e.*, yards per hour) while minimizing resuspension of sediments. For example, the depth of cut, transfer rate while underwater, lift speed through the water column, and hang-time above the river to allow for equilibrium and drainage were evaluated.

Another factor that contributed to bucket overfilling was the number of dredging passes used to achieve design depth. On December 5-6, 2005, the full depth of sediment removal was consistently achieved through one bucket pass in each dredge swing arc. However, on December 7-8, 2005 and December 10, 2005, the dredging operator revised dredging techniques by taking two passes per arc to achieve design depth. This modification resulted in the bucket being 50-60 percent full on each pass. An increase in decant water was also observed with this technique, but the drain water was less turbid. On December 10, 2005, the bucket drain hang-time was increased to allow complete decanting prior to placement in hopper barge.

The usage of a guide barge was also tested during the Pilot Study. On December 5-6, 2005, during dredging of the 11-foot and 13-foot cut sections, a guide barge was spudded in place to hold the dredge and hopper barge in position. To facilitate repositioning of the guide barge from the 11-foot to the 13-foot cut sections, the spuds were lifted and then reinserted into the river bottom once the proper location was reached. Since the spudding activity has the potential to resuspend sediment, subsequent moves within a cut section were performed by winching and cabling the dredge into position. It was agreed with the dredging contractor that the spuds would not be inserted into a location that had already been dredged. Therefore, repositioning of the guide barge was optimized to minimize the number of moves required. For the 15-foot cut section, it was agreed, prior to initiating the field work, that the guide barge would not be used for the 15-foot cut section due to the restrictions on river width imposed on the navigation channel. Therefore, during dredging of the 15-foot section on December 7-8, 2005 and December 10, 2005, the guide barge was not used, and the barge was positioned with a tugboat.

In summary, several Best Management Practices were tested during the Pilot Study. Optimal dredging operations with minimal resuspension were achieved on December 7-8, 2005 and December 10, 2005 by employing the following Best Management Practices:

- Operating with an environmental clamshell bucket.
- Optimizing the environmental bucket cycle time between grabs by adjusting horizontal transfer speed while underwater, lift speed through the water column, and hang-time above the river.
- Using two passes per dredge swing arc to achieve target depth.
- Optimizing the use of winching and cabling in place of tugboats for repositioning the rinse tank.

The inclusion of the rinse tank in the dredging operation proved to be the least effective Best Management Practice. The rinse tank was used to remove sediments from the dredge bucket prior to making the next grab. However, despite efforts to operate efficiently (*e.g.*, tugboat assisted positioning of the rinse tank), cycle times were impacted with minimal solids captured by the rinse tank. The dredging contractor reported estimates of the volume of dredged material that remained in the rinse tank at the end of each day. In general, approximately 2 cubic yards/day of very loose sediment accumulated in the rinse tank, representing a minute fraction of the daily dredged volume. The rinse tank volume was described as fluffy sediment material, and since the density of this material is unknown, a mass conversion is not possible. Using this rate, which is a best case assumption, over the 5 days of active dredging, the rinse tank was estimated to capture 10 cubic yards of material. This volume represents a capture of approximately 0.3 percent of the total dredged volume (4,000 cubic yards) that might have otherwise been lost to the river. The actual sediment captured by the rinse tank is likely far less on a mass basis.

4.6 BATHYMETRIC SURVEYS

Daily bathymetric surveys were conducted by Jay Cashman, Inc. each time dredging operations were completed in an area. In addition to these daily surveys, pre-dredging and post-dredging bathymetric surveys were performed by Rogers Surveying, Inc. The pre-dredging survey was performed on November 28, 2005, and the post-dredging survey was conducted on December 11, 2005 to confirm that the targeted dredging elevations had been achieved. Additional post-dredge surveys were conducted on February 15, 2006 and April 18, 2006. These bathymetric surveys were used to confirm the accuracy of the dredging operation. By verifying that all areas were not over-dredged more than one foot below targeted elevations, it was confirmed that deeper, more contaminated materials had not been exposed. Consequently, backfilling of over-dredged areas was not necessary.

4.7 SEDIMENT PROFILE IMAGING

SPI technology was used to provide distinct images of the freshly deposited suspended matter or disturbed sediments on top of the undisturbed bottom sediments. Two SPI surveys were conducted on the Lower Passaic River: one in June 2005 and one in December 2005. The first SPI survey was conducted as part of the overall Lower Passaic River Restoration Project and was performed along a series of cross-river transects from RM0 at the confluence of the Lower Passaic River and Newark Bay to RM15.5 in Garfield, New Jersey (Germano and Associates, Inc., 2005). The second SPI survey occurred on December 13, 2005 (3 days after the completion of the Pilot Study) and was performed in and around the Pilot Study Dredge Area to quantify the thickness of the redox potential discontinuity (Appendix E) to qualitatively evaluate residuals.[10] Images were collected at 15 stations (9 stations within the established sediment-coring grid and 6

[10] Sediments in the oxic zone tend to be brownish-red in color due to the high dissolved-oxygen level while sediments in the reduced (or anoxic) zone tend to be black in color. The zone between the oxic and reduced sediments is known as the redox potential discontinuity layer. Sediments in the redox potential discontinuity layer are usually grey in color, representing the transition in redox potential.

stations around the sediment-coring grid). At each station, 3 replicates were taken for a total of 45 station-replicates.

During the SPI surveys on the Lower Passaic River, no direct measurements of the redox potential were collected. Instead, the apparent redox potential discontinuity depth was indirectly estimated by assessing color changes in the sediment using the SPI images. The redox potential discontinuity boundary was estimated by visually tracing the color change (brownish-red to grey boundary) across the SPI image. Then, the area of the image from the sediment-water-interface to this boundary was calculated and divided by the width of the image to obtain an estimate of the average redox potential discontinuity layer depth for the image. Table 4-2 contains redox potential discontinuity depths for SPI surveys conducted in June and December 2005 (refer to Figures 4-2 and 4-3 for maps of SPI locations and Appendix E for further discussion). The December 2005 data are divided into two groups: stations located inside and outside the Pilot Study Dredge Area or sediment coring grid. The June 2005 data represent stations located both upriver and downriver of the Pilot Study Area. Further discussion of these data are presented in Section 8.4; in general, river flow data suggest that storm events occurring prior to the dredging could be responsible for the deeper redox potential discontinuity layers, especially since thick layers are observed both inside and outside the Pilot Study Area.

4.8 DEMOBILIZATION

The dredging contractor demobilized and returned equipment to their yard in Staten Island on December 10, 2005. No issues associated with demobilization were encountered.

4.9 DREDGED MATERIALS MANAGEMENT

The technical feasibility and economic viability of two sediment decontamination technologies were evaluated as part of the Pilot Study to determine whether a valuable product, such as manufactured soil or construction-grade cement, could be produced at full scale. These technologies included a thermo-chemical destruction process (Cement-Lock® in Bayonne, New Jersey) and a sediment washing process (BioGenesis in

Keasbey, New Jersey). The decontamination demonstration aspect of the Pilot Study was implemented under the New Jersey-New York Harbor Sediment Decontamination Technology Demonstration Program. Results from the decontamination aspect of the Pilot Study are available under a separate vendor report on the public website (www.bnl.gov/wrdadcon).

The material dredged from the Pilot Study Dredge Area was placed directly into a hopper barge, which was cabled alongside the dredge barge. Dredged material was assumed to have similar geotechnical characteristics and similar contaminant levels as sediments sampled during the July 2004 coring program. No overflow or decanting of the hopper barges occurred during the Pilot Study, per the Federal Consistency/Water Qualification Certification. Once the hopper barge was properly filled, a tugboat transported the hopper barge to the near-shore materials handling staging/storage area at the Bayshore Recycling, Inc., located on the Raritan River in Keasbey, New Jersey. The *SEI 3000* departed the Pilot Study Area on December 6, 2005 at 1640 hours EST and arrived at the decontamination facility on December 6, 2005 at 2300 hours EST for a transit time of 6 hours and 20 minutes. The SEI 3003 departed the Study Area on December 10, 2005 at 1530 hours EST and arrived at the decontamination facility on December 10, 2005 at 2030 hours EST for a transit time of 5 hours. The hopper barges were compatible with available draft and other horizontal and vertical clearance limitations on the Lower Passaic River, Newark Bay, and along the haul route to the decontamination facility. Consequently, no transit time delays were reported.

While the hopper barges arrived in the decontamination facility in December 2005, offloading did not occur until January 2006 due to delays. The volume of material (solids and water) in the two hopper barges was measured by BioGenesis at the sediment offloading facility. Hopper barge *SEI 3000* contained 2,420 cubic yards of material (solids and water), and the hopper barge *SEI 3003* contained 3,180 cubic yards of material (solids and water). This material was offloaded and placed in an upfront storage facility (a 730-foot converted ore/grain carrier) over a period of five shifts at an average rate of 490 to 640 cubic yards/shift. During the offloading, the dredged material was screened with a sieve size of 0.25 inch. A total of 118 tons of oversized material was removed and disposed. An estimated 1,290 cubic yards of water was removed from the two hopper barges and processed through the wastewater treatment portion of the BioGenesis Sediment Washing Facility during five operational days from January 13, 2006 to January 25, 2006.

From the storage carrier, the dredged material was then pumped directly across the dock to the warehouse-enclosed BioGenesis sediment washing demonstration facility. For the thermo-chemical destruction, a small portion (619 cubic yards) of the untreated dredged material from the storage carrier was dewatered by BioGenesis using a belt filter process (resulting in 170 cubic yards of dewatered sediment). The dewatered material was then transported to a near-shore processing facility (ENDESCO Clean Harbors, L.L.C.) in Bayonne, New Jersey to undergo treatment using Cement-Lock® process with a rotary kiln, which produces construction-grade cement as a beneficial use product. The remaining sediment (2,269 cubic yards, not dewatered) was treated using the BioGenesis sediment washing process to produce a manufactured soil product that could be used in a number of land-based applications, such as upland remediation and landscaping. Treated water was discharged under permit to the Middlesex County Utilities Authority.

4.10 DEVIATIONS FROM WORK PLAN ON DREDGING OPERATIONS

Three deviations from the Work Plan were reported for the dredging operations during the Pilot Study. First, due to the improper installation of the depth sensor equipment, the dredging contractor manually estimated the bucket depth using paint markings on the bucket chain (as traditionally used in navigational dredging operations) on December 5-6, 2005. Consequently, impacts on dredging performance and vertical accuracy were observed. Second, dredging operations were scheduled for five consecutive days starting on December 5, 2005 and ending on December 9, 2005. However, due to a severe snowstorm and gale force winds on December 9, 2005, no dredging was performed due to health and safety concerns for the monitoring crew. Instead, the work originally scheduled for December 9, 2005 was performed on December 10, 2005. Lastly, due to access issues associated with the base station site and radio interference, the dredging contractor decided to use the back-up Trimble GPS/ClamVision® system as the primary system to determine bucket positioning instead of the RTK GPS system. This deviation from the Work Plan did not impact the evaluation of vertical accuracy of the bucket since the ClamVision® positioning system and depth pressure sensors provide compatible vertical data.

5.0 DREDGING PERFORMANCE

A major objective of the Pilot Study was to evaluate dredging performance in terms of productivity and vertical accuracy. Data collected to evaluate these characteristics included bathymetric surveys, *ex-situ* volume measurements, work time, and cycle times. This performance evaluation is specific to the Pilot Study (which was designed to evaluate production environmental dredging), the dredging equipment employed, and the site examined.

5.1 DREDGING PROGRESS

Records of dredging operations are provided in the *Final Completion Report* (Jay Cashman, Inc., 2005a; refer to Appendix A). For each day of operation, the dredging contractor completed four field logs: Daily Activity Summary, Daily Movement Log, Daily General Log, and an Engineer Daily Report.[11] Together, these field logs provide information on equipment set-up, daily work schedule, health and safety, dredging progress, hopper barge ("scow") loading, vessel movement, equipment repairs, equipment downtime, client-directed standby time, and surveying activities. Additional material provided in the *Final Completion Report* (Jay Cashman, Inc., 2005a; refer to Appendix A) include daily estimates of ullage, ClamVision® data logs and drawings, and tide levels for the Lower Passaic River. Table 5-1 provides weather conditions in Newark, New Jersey during the Pilot Study, and Table 5-2 provides field notes compiled by the field oversight engineer, including deviations from the Work Plan.

During dredging operations, measurements of dredging progress were recorded by ClamVision® dredging software. Each bucket grab was recorded and color-coded based

[11] Since dredging activities during the Pilot Study were not designed for navigational purposes, ENG FORM 4267 was not used by the dredging contractor. However, relevant production information requested on ENG FORM 4267 is available by reviewing the four field logs provided by Jay Cashman, Inc., material in the *Jay Cashman, Inc. Final Completion Report* (refer to Appendix A), and the weather conditions provided in Table 5-1.

on cut depth. An information box provided instant feedback showing current depth, final project depth, target depth, current bucket depth, and an indication as to whether the bucket was closed and sealed. Appendix A contains maps of the bucket locations for each day. Figure 5-1 illustrates the cumulative area dredged over the course of the five days. The portion of Figure 5-1 shown in yellow (all of the 13-foot cut and a large portion of the 11-foot cut) was dredged without the aid of the Cable Arm, Inc. depth sensor equipment. Instead, paint marks on the bucket chain estimated bucket depth until the sensors could be properly repaired. Beginning December 6, 2005 at 1735 hours EST (until the end of the Pilot Study), the depth sensors were functional and operating correctly. The areas dredged with the depth sensors functioning are shown in red on Figure 5-1.

5.2 CYCLE TIME AND WORK TIME ANALYSES

5.2.1 CYCLE TIME

Cycle time is defined as the total time required to dredge and to close the bucket, to raise it through the water column, to release dredged material into the hopper barge, to rinse the bucket in the rinse tank, and to reposition the bucket at the sediment bottom for the next bucket grab. Cycle times for the Pilot Study were evaluated using three different data sources: field oversight notes, data logs available as part of the ClamVision® software, and Jay Cashman, Inc. field logs including videos of dredging operation (Appendix A).

Cycle times were first estimated in the field by the field oversight engineer based on periodic timing of cycle times. They were then re-calculated at the completion of the Pilot Study with the visual inspection of over 16 hours of dredging contractor video logs and the evaluation of ClamVision® data, which recorded each bucket grab during the dredging operation.[12] Refer to Appendix F for back-up tables on the cycle time evaluation with the ClamVision® data. The raw ClamVision® data were screened using

[12] The improper installation of the pressure depth sensors on December 5 and December 6 did not affect the capability of the ClamVision® software to record dredging progress data.

the Jay Cashman, Inc. daily activity summary and daily movement logs to identify and filter out non-dredging times. According to the *Technical Guidelines for Environmental Dredging of Contaminated Sediments* (USACE, 2008a), typical environmental dredging cycle times range from 2 minutes to 8 minutes. Jay Cashman, Inc. recorded a portion of the Pilot Study dredging operation via video media. A review of these video indicated that cycle times for the Pilot Study were between 1 minute and 5 minutes. Consequently, the ClamVision® cycle time data were further screened for unrealistic times that were either less than 0.75 minutes or greater than 5.5 minutes. A summary of cycle time data is presented in Table 5-3.

In general, similar cycle times were obtained using the three different data sets. Cycle times obtained from the video logs were slightly higher than cycle times estimated using the ClamVision® data. This difference is likely associated with timing error in the visual inspection of the video and the period of time captured by the video logs. Approximately half of the effective working time (including dredge movement) was recorded by the available video logs. Cycle times corresponding to the screened ClamVision® data are likely more representative of the true Pilot Study cycle times since the ClamVision® logs include records of every bucket grab taken by the dredge compared to the cycle times estimated by the field oversight engineer and video logs, which are based on a smaller time period.

According to the screened ClamVision® data, the dredge operated with an average cycle time of 2.5 minutes and typical daily cycle times ranged from an average of 1.55 to 3.20 minutes (Table 5-3).[13] It was estimated that the rinse tank, used to clean the dredge bucket between each cycle, accounted for approximately a 30-second component of the cycle time. Rinse tank times were recorded in the field logs starting from the swing time from the barge after release of the sediment to the rinse tank and then back to the bucket position for the subsequent cut at the top of the water elevation. This time period varied

[13] The "range of typical cycle time" was calculated using approximately 90 percent of the data that were either greater than 0.75 minutes or less than 5.5 minutes.

depending on the placement of the rinse tank barge (*i.e.*, tugboat assisted positioning versus stationary positioning). Tugboat-assisted positioning of the rinse tank barge reduced the overall cycle time since this method reduced the time required to extend the dredge arm to reach the tank; however, the resuspension of sediment associated with the tugboat operation was noticeable. Stationary positioning of the rinse tank barge slowed the dredging operation and added time to the overall cycle time.

5.2.2 WORK TIME

A working time analysis was performed to evaluate the effective working time and the dredging time. These two standard measures of time are required to calculate dredging production (refer to Section 5.4 for productivity calculations). Effective working time (also referred to as "operating time") is the time when actual production is taking place. Dredging time is the effective working time plus the non-effective working time (also referred as "allowable downtime") (USACE, 1994). The non-effective working time is further defined as the time when the dredge is operational but no production is taking place, such as minor operating repairs and/or maintenance, changing sediment barges, moving the dredge, agency inspections, and waiting for direction from owner/engineer. The effective working time and the dredging time are also used to determine the effective working time efficiency (EWTE), which is the ratio of the two measures. This ratio is commonly known as the "uptime" and expressed as a percentage.

While the non-effective working time accounts for minor operating repairs and/or maintenance, major repairs along with other elements are incorporated into the "lost time." For this work time analysis, major operating repairs and/or maintenance are defined as repairs/maintenance requiring more than one-half hour to complete. Lost time plus the dredging time equal the "dredging duration," which is typically used to calculate seasonal efficiency and sustained production rate. Potential impacts to the dredging duration (and consequently to seasonal efficiency and sustained production) are identified and discussed in Section 5.2.3; however, the calculations of seasonal efficiency and sustained production rate are not presented due to the duration of the Pilot Study. For more detail on effective working time and non-effective working time refer to *Technical Guidelines for Environmental Dredging of Contaminated Sediments* (USACE, 2008a).

The working time analysis for the Pilot Study was performed using Jay Cashman, Inc. field logs. A breakdown of the average work day is presented in Figure 5-2, and breakdowns for the individual days are presented in Figure 5-3. For this analysis, working time was categorized as setup, operating time, equipment movement, downtime, lost time, and client-directed standby. To calculate working time, the data provided in the field logs were adjusted to accurately reflect dredging activities. Adjustments were based on the ClamVision® cycle time data and personal communication with Jay Cashman, Inc; these adjustments include:

- Jay Cashman, Inc. daily movement log was used in conjunction with ClamVision® data to determine the time that corresponded to dredge movement that was not logged in the Jay Cashman, Inc. daily activity summary (refer to Appendix F). This time corresponds to non-effective working time, and it was subtracted from the operating time and added to the equipment movement time. Adjustments of the non-effective working time included 1.81 hours on December 5, 2005; 1.16 hours on December 6, 2005; 1.41 hours on December 7, 2005; 0.37 hour on December 8, 2005; and 0.63 hour on December 10, 2005.
- <u>December 6, 2005</u>: Jay Cashman, Inc. daily activity summary indicates a dredging operation time of 7.68 hours; however, this time is likely incorrect and the operating time was likely less. According to the log, from 1730 hours EST to 1930 hours EST, *SEI 3003* was being loaded in Area E3, and then from 1930 hours EST to 2030 hours EST, barges were shifted around and dredging continued. Furthermore, between 1930 hours EST and 2030 hours EST, field notes indicate that the dredge was moved to the 15-foot MLW section, the guide barge dismantled, and the rinse tank relocated to the port side of the dredge (no mention of dredging operation time). Meanwhile, records on ClamVision® data log do not go beyond 1849 hours EST. Since the ClamVision® system was fully operational after 1735 hours EST, it is unlikely that the software stopped logging data and dredging likely ceased at 1849 hours EST.

Consequently, based on these lines of evidence, operating time for December 6, 2005 was modified to 6.17 hours (assuming dredging operations ceased at 1900 hours EST) and the difference of time (*i.e.*, 1.51 hours) was considered equipment movement time.

- December 7, 2005: Jay Cashman, Inc. daily activity summary indicates that from 1545 hours EST to 1730 hours EST, dredging operations ceased for the day and surveying activities took place. However, a bathymetric survey was not performed on December 7, 2005. Since surveying times cannot be estimated from the logs and surveying durations are not recorded for any other days of the Pilot Study, the working day was considered to have ended at 1545 hours EST.
- December 8, 2005: Jay Cashman, Inc. daily activity summary indicates that from 0630 hours EST to 0915 hours EST, the dredging contractor was onboard Wood I and that operations were on client-directed standby. The duration of equipment setup was not recorded in the logs; therefore, 0.5 hour of equipment setup time was assumed based on previous daily activities and this time was correspondingly subtracted from the client-directed standby time.
- December 9, 2005: While the dredging contractor proceeded with equipment setup, no dredging activities occurred on December 9, 2005 due to weather conditions that presented a health and safety concern for the monitoring crew. Consequently, dredging operations were on client-directed standby time. The duration of equipment setup was not recorded; therefore, 0.5 hours were taken from client-directed standby time for equipment setup.
- December 10, 2005: The duration of equipment setup was not recorded in the Jay Cashman, Inc. daily activity summary; therefore, 0.5 hours were subtracted from the client-directed standby time and added to equipment setup.

The average work day of 10.5 hours/day represents the total hours on the site as determined from the Jay Cashman, Inc. field logs. However, to achieve the objectives of the Pilot Study, client-directed standby was required to allow for alignment of the dredging activity with the resuspension monitoring activities. Client-directed standby time is considered an artifact of the Pilot Study design, and not part of the actual dredging time (*i.e.*, standby time was not considered non-effective working time). For example, longer dredging times were recorded on the first three days of dredging operations (December 5-7, 2005) while the last two days of dredging operated on a restricted numbers of hours to fulfill the Pilot Study objectives of five days of monitoring activities. After accounting for client-directed standby time and lost time, the average work day (which equals the work day minus the client-directed standby time and lost time, or simply the dredging time) was 8.3 hours/day. During the work day, the average operating time was 5.0 hours/day.

For the entire Pilot Study, the EWTE was 60 percent. This percentage of uptime is typical for mechanical dredging operations in the New York Harbor region (USACE, 2006). However, during the Pilot Study, different operational controls and Best Management Practices were tested, so the presentation of an *average* uptime value does not accurately represent the Pilot Study. For example, the first two days of the Pilot Study (December 5, 2005 and December 6, 2005) had longer dredging times with shorter effective working time due to initial setup, changing barge, and ClamVision® depth sensor problems. Optimal operational controls and Best Management Practices were achieved later in the Pilot Study on December 7-8, 2005 and December 10, 2005. The EWTE reflects this optimization with EWTE of 45 percent for the first two days, and EWTE of 79 percent at the end of the Pilot Study. The EWTE for the first two days of the Pilot Study is lower than the uptime range (55 to 70 percent) that is typical for sediment remediation projects (USACE, 2008a) and is directly associated with the project shakedown. However, the EWTE for the remainder of the Pilot Study is higher than the typical environmental dredging range and actually resembles ranges typically seen for navigation dredging nationwide (70 to 85 percent; USACE, 2008a).

5.2.3 Potential Impacts From Delays

Mobilization delays, vessel traffic, barge delays, weather conditions, equipment movement, and equipment downtime all have the potential of impacting dredging operations and dredging performance. During the Pilot Study, equipment movement and equipment downtime impacted dredging performance.

- Mobilization Delays: While mobilization of the Pilot Study was impacted by the malfunctioning of the railroad swing bridge, dredging equipment did arrive to the site on-time and operations began on schedule on December 5, 2005. Mobilization delays did impact the improper installation of the depth sensor equipment; these impacts are discussed below in equipment downtime.
- Vessel Traffic: While other vessels were present at the Pilot Study Area (*e.g.*, skimmer vessels, project monitoring vessels, and press event vessel), this traffic did not impact dredging operations or cause delays during the Pilot Study since no barge movement was necessary to accommodate passing vessels. "Standing by" for navigation traffic is considered non-effective working time.
- Barge Delays: The Pilot Study was not impacted by barge delays. Two hopper barges were loaded with dredge material and transport by tugboat without delay to the decontamination facility in Keasbey, New Jersey. Delays were associated with sediment offloading of the dredged material and with the construction of the sediment offloading facility and are discussed in the vendor decontamination reports. These delays are not associated with the Pilot Study since they occurred after the dredging operation was completed. However, this delay did result in a financial claim to NJDOT from Jay Cashman, Inc. due to the demurrage of the barges.
- Weather Conditions: During the Pilot Study, an entire working day (December 9, 2005) was lost due to inclement weather, and the operations had to be extended an additional day in the field beyond the planned schedule. However, this postponement of dredging activities on December 9, 2005 was due to safety concerns for monitoring personnel – the dredging contractor was prepared to work. Because the Pilot Study was conducted near the end of the normal dredging season, this winter storm-related delay is considered atypical of conditions expected to be encountered during a full-scale dredging operation. In addition, it represents an unusual portion of the Pilot Study compared to a full-scale operation. Consequently, this weather delay was not included in the working time analysis and did not impact dredging performance. Moreover, this type of delay would be considered lost time, which would not affect dredging time.

- Equipment Movement: The movement of barges, dredge, and rinse tank within the dredging area are unavoidable in any dredging operation. Equipment movement accounted for an average of 1.7 hours/day. Moving equipment is considered allowable downtime (*i.e.*, non-effective working time). Impacts of equipment movement are reflected in the working time analysis and productivity calculations.
- Equipment Downtime: The improper installation of the depth pressure sensors caused work stoppage during December 5-6, 2005 (1.92 and 2.83 hours, respectively). The potential delays associated with the sensor malfunctions were minimized by the presence of an experienced crane operator, who was capable of operating the environmental dredge bucket manually until the depth sensors could be repaired. The sensor equipment problems were corrected during a planned work stoppage and barge change out on December 6, 2005. After repairs were completed, the depth pressure sensors remained operational for the remainder of the Pilot Study, and no further delays were encountered due to equipment downtime. Most of the time spent troubleshooting and making repairs (4.25 hours)[14] is considered non-allowable downtime (*i.e.*, lost time). Impacts of equipment downtime are reflected in the working time analysis and productivity calculations.

5.3 DREDGED VOLUME ESTIMATES

The dredged volume was estimated using three different techniques: comparing the pre-dredge river elevations to the post-dredge river elevations, summing the daily volume of dredged material, and examining the *ex-situ* volume of dredged material removed.

5.3.1 PRE-DREDGE AND POST-DREDGE EVALUATION

One approach to estimating the volume of sediments removed by dredging is to compare the river bottom elevation in the Pilot Study Dredge Area before and after dredging operations. Cross-sections of the Pilot Study Dredge Area throughout the dredging

[14] The total time spent making repairs was 4.75 hours (0.5 hour non-effective working time and 4.25 hours lost time).

operation are presented in Figure 5-4. Note that Figure 5-4a shows the positioning of each transect in a plan view while the other figures in the set show a cross-sectional view.

For this volume estimation, the bathymetric surveys that were conducted on November 28, 2005 (representing the pre-dredge elevation) and December 11, 2005 (representing the post-dredge elevation) were evaluated. Bathymetric data were used to create a surface using a triangular irregular network in the geographic information system (GIS) software. Surfaces were then compared to estimate dredged volumes. The depression in the river bottom caused by the Pilot Study is visible through this comparison and presented in Figure 5-5a and Figure 5-5b (showing areas where the river bottom elevation changed more than 1 foot). The limits of dredging were further constrained by plotting the bucket coordinates available through the ClamVision® data (Figure 5-6). Together, these data define the actual Pilot Study Dredge Area with approximate dimensions of 170 feet wide by 290 feet long (1.2 acres). Within this boundary, an estimated 3,800 ±100 cubic yards of sediment were removed during the Pilot Study.[15] Note that Rogers Surveying, Inc., who conducted the pre-dredge and post-dredge surveys, reported an estimated 3,710 cubic yards removed. This value is within the statistical error of 3,800 ±100 cubic yards.

After completion of the Pilot Study, the dredging contractor reported that the Pilot Study Dredge Area was not entered correctly into the dredging positioning software. More specifically, where the design plans showed the bottom or toe of slope, it was configured in the ClamVision® software as the top of slope. This discrepancy resulted in the dredging operation missing 5 to 10 feet at each edge of the dredge area and each transition in elevation, but the total dredged area was not impacted. The programming error was evident by viewing post-dredging cross-sections of the river (Figure 5-4 series).

Additional post-dredge surveys were conducted on February 15, 2006 and April 18, 2006. These surveys were used to calculate the volume of sediment deposited in the Pilot

[15] Volume error was estimated assuming a 1-inch error on the bathymetric data across the Pilot Study Area.

Study Dredge Area after dredging. A comparison of sediment volume filled from December 11, 2005 to April 18, 2006 can be found in Table 5-4. (Note that the February 2006 post-dredging bathymetric survey is also presented in the Figure 5-4 cross-sectional view series.) By February 2006, approximately 35 percent of the dredged volume had already been filled by bed movement and natural deposition. By April 2006, about 60 percent of the volume had been filled in. This accumulation of solids cannot be converted into a "sedimentation rate" since the dredging activities created a depression in the river that was preferentially accumulating bed load.

5.3.2 DAILY BATHYMETRIC SURVEY EVALUATION

Another approach for estimating the total volume of sediments removed is to examine the daily bathymetric surveys and sum the daily dredged volumes together. Jay Cashman, Inc. conducted a bathymetric survey at the end of each day or at the beginning of the following day (before dredging operations began) to characterize daily dredging activities. Unlike the pre-dredge and post-dredge bathymetric surveys that cover the full extent of the Pilot Study Dredge Area, the daily bathymetric surveys include elevation data only for the portion of the dredge area that was dredged on a particular day. Daily bathymetric surveys are available on December 5, 2005, representing the 13-foot MLW targeted elevation area and on December 6, 2005, representing the 11-foot MLW targeted elevation area. No survey was conducted on December 7, 2005 due to battery problems on the *Alex D*, and the daily bathymetric survey scheduled for December 8, 2005 was collected on the morning of December 9, 2005. Consequently, the December 9 survey represents the cumulative dredging activity from December 7-8, 2005 in portions of the 15-foot MLW targeted elevation area. The last daily bathymetric survey was conducted on December 10, 2005, which completed the 15-foot MLW targeted elevation area.

An estimate of the daily dredged volumes was performed by comparing the daily river elevations to the pre-dredge river elevation (collected on November 28, 2005 by Rogers Surveying, Inc.). For this comparison, each daily bathymetric survey was evaluated using the boundaries of the actual Pilot Study Dredge Area. Bathymetric data were used to create a surface using a triangular irregular network in the GIS software. Surfaces were then compared to estimate dredged volumes. The extent of the survey was compared to the daily bucket positions provided by the ClamVision® data (Figure 5-6). Note that the dredging activities for December 7, 2005 and December 8, 2005 were separated from the cumulative December 9, 2005 bathymetric survey using the ClamVision® data. The total volume of dredged sediments based on the daily bathymetric surveys was 4,000 ±200 cubic yards, which is statistically the same as the volume computed when comparing the pre-dredge and post-dredge surveys 3,800 ±100 cubic yards. Both values were bounded by the same actual Pilot Study Dredge Area. A breakdown of daily dredged volumes is tabulated in Table 5-5.

Note that the total volume of dredged sediment as calculated by Jay Cashman, Inc. using the daily bathymetric surveys was 4,150 cubic yards. This value is within the statistical error of 4,000 ±200 cubic yards.

5.3.3 EX-SITU VOLUME MEASUREMENTS

Another technique for estimating the dredged volume is to calculate the *ex-situ* dredged volume in the hopper barges. The volume of dredged material in each hopper barge was estimated by the contractor by examining markings on the four sides of the barge and by comparing the change in submerged depth to the hopper barge depth. According to standard operating procedures, the submerged depth of the hopper barge (in intervals of 6-inches) is converted to a dredged volume using a conversion table for each corner of the hopper barge. These four volumes are then averaged to obtain the final dredged volume.

The volume of material (solids and water) in the two hopper barges was measured by BioGenesis at the sediment offloading facility in Keasbey, New Jersey. Hopper barge *SEI 3000* contained 2,420 cubic yards of material (solids and water), and hopper barge *SEI 3003* contained 3,180 cubic yards of material (solids and water). An estimated 1,290 cubic yards of water was removed from the two hopper barges from January 13, 2006 to January 25, 2006. Based on these values, the estimated *ex-situ* dredge volume was 4,310 cubic yards, which is greater than the *in-situ* dredge volume of 4,000 ±200. The difference in values is attributed to sediment bulking (estimated 7 percent bulking), which is expected due to water entrainment during dredging.

The *ex-situ* sediment volumes measured by BioGenesis in January 2006 are significantly different than the daily ullage measurements provided by Jay Cashman, Inc. since the two contractors were using different methods to measure the *ex-situ* volume. BioGenesis measured the total volume of material in the barge (solids and water). In addition, they measured the volume of water removed from the top of the dredged sediments after the solids settled. In contrast, Jay Cashman, Inc. performed bucket-drops to the mudline in the barge at the end of each day. Since the ullage measurement occurred at the end of each day, the mud-line was not level and fine-grained solids likely did not have time to settle. Field logs from Jay Cashman, Inc. indicate that the mudline at the corner of the barge varied by 5 feet in height on the *SEI 3000*, and it varied 3 feet in the *SEI 3003*. Consequently, the ullage measurement represents a subjective estimation on the dredged volume and likely underestimates the *ex-situ* sediment volume.

5.4 PRODUCTIVITY

The daily dredged volumes were combined with the work time analysis to calculate maximum and average operating production rates. The "maximum operating production rate" is based on the *in-situ* volume of sediment removed during the effective working time while the "average operating production rate" is based on the volume of sediment removed during the dredging time. In addition, a site-specific production rate was calculated as a function of total hours on site including client directed standby time and lost time. A summary of these daily productivity rates is presented in Table 5-6 and Figure 5-7.

The daily maximum operating production rates ranged from 120 cubic yards/hour to 240 cubic yards/hour while the maximum operating production rate for the duration of the Pilot Study was 160 cubic yards/hour. Daily production rates varied by a factor of two because the Pilot Study was designed to test and optimize operational controls and Best Management Practices. In addition, dredging activities were restricted on December 8, 2005 to fulfill contract requirements that dredging activities would extend over five days to accommodate the water quality monitoring program. Consequently, productivity rates were re-calculated (as presented on Table 5-6) to accommodate days when dredging techniques were being tested (December 5-6, 2005) opposed to days when Best Management Practices and operational controls were optimized (December 7-8 and 10, 2005). The maximum operating production rate for the first two days of the Pilot Study was 200 cubic yards/hour; however, this rate decreased to 130 cubic yards/hour later in the Pilot Study when Best Management Practices were optimized. Productivity decreased when Best Management Practices were implemented because these practices yielded longer cycle times and less volume removed per dredge. For example, a stationary rinse tank and longer hang times resulted in longer cycle times while the implementation of two passes per arc to achieve design depth reduced the volume removed per bucket grab.

In contrast, the average operating production rate increased from 90 cubic yards/hour for the first two days of the Pilot Study to 100 cubic yards/hour later in the Pilot Study when Best Management Practices were optimized. The increase in average operating production rate reflects the change in the effective working time over the course of the Pilot Study and the increase in the uptime from 45 percent at the beginning of the Pilot Study to 79 percent later in the Pilot Study. These rates are mathematically equivalent to the removal of 2,200 cubic yards and 2,500 cubic yards of dredge material (respectively) over a 24-hour period. Note that this mathematical conversion does not represent a production rate across a full operating season, nor does it incorporate impacts from clean-up passes or constraints on allowable times for dredging due to operational and quality of life issues. It should also be noted that during a full-scale operation, more routine maintenance may be required to account for the "wear and tear" on dredging equipment that is associated with a longer work day; increased routine maintenance would subsequently reduce the uptime.

The site-specific production rate, which is a function of the total hours on site including client directed standby time and lost time, did not change during the Pilot Study with a rate of 76 cubic yards/hour. During the first two days of dredging operations, the work day was relatively longer (approximately 14 hours), reflecting longer setup time and barge movement. Relatively large amounts of material were dredged over a short period of operating time. Conversely, once Best Management Practices and operational controls were optimized, less material was dredged during shorter operating times, but the work day (7 to 9 hours) included larger periods of client-directed standby time to accommodate the water quality monitoring program.

5.5 VERTICAL DREDGING ACCURACY

As per the *NJDOT Plans and Specifications for Environmental Dredging in the Lower Passaic River* (NJDOT, 2005), the dredging contractor's goal was to achieve a vertical dredging accuracy of ±6 inches (for this production dredging). The actual vertical accuracy achieved during the Pilot Study was evaluated by comparing the pre-dredging survey, daily surveys, and post-dredging survey data.

For this evaluation, soundings on a 3-foot by 3-foot horizontal grid were plotted to determine their location with respect to the proposed Pilot Study Dredge Area. Soundings that fell within one of the three distinct dredge depth areas (*i.e.*, 11 feet MLW, 13 feet MLW, or 15 feet MLW) were compared to the appropriate targeted design elevation. When all the bathymetric data were considered, the vertical dredging accuracy for the Pilot Study was calculated (Table 5-7a):

- The 15-foot MLW area was dredged with the aid of the Cable Arm, Inc. ClamVision® positioning software with depth sensors. Dredging operations in this area were also optimized following Best Management Practices and included two passes per arc to achieve design depth. Approximately 79 percent of the area achieved the target design elevation within a tolerance of ±6 inches. Approximately 90 percent of the area achieved the target depth within a tolerance of ±9 inches. Approximately 95 percent of the 15-foot MLW area achieved the target design elevation within a tolerance of ±12 inches (Table 5-7a; vertical accuracy calculated considering all bathymetric data).

- The 13-foot MLW area was dredged without the depth sensors. Approximately 65 percent of the area achieved the target design elevation within a tolerance of ±6 inches. Approximately 85 percent of the area achieved the target depth within a tolerance of ±9 inches. Approximately 95 percent of the 15-foot MLW area achieved the target design elevation within a tolerance of ±12 inches (Table 5-7a; vertical accuracy calculated considering all bathymetric data).
- The 11-foot MLW area was dredged both with and without the depth sensors. With the depth sensor, approximately 69 percent of the area achieved the target design elevation within a tolerance of ±6 inches. This accuracy increased to 81 percent within a tolerance of ±9 inches and 90 percent within a tolerance of ±12 inches (Table 5-7a; vertical accuracy calculated considering all bathymetric data).

After completion of the Pilot Study, the dredging contractor reported that the Pilot Study Dredge Area was not entered correctly into the dredging positioning software (ClamVision®). More specifically, where the design plans showed the bottom or toe of slope, it was configured in the ClamVision® software as the top of slope. This discrepancy resulted in the dredging operation missing 5 to 10 feet at each edge of the dredge area and each transition in elevation. This programming error was evident by viewing post-dredging cross-sections (Figure 5-4 cross-sectional series). Moreover, the initial accuracy calculations assumed that a distinct elevation change existed between dredge cuts; however, a 3-foot side slope exists between dredge cuts. Consequently, the vertical accuracy was re-calculated. Points that fell within 3 feet of the interior dredge cut and within 10 feet of the outside edge of the dredge area were omitted. After correcting for the ClamVision® programming error and considering the 3-foot side slopes between the dredge cuts, the accuracy of the dredging equipment was re-calculated (Table 5-7b).

- The 15-foot MLW area was dredged with the aid of the Cable Arm, Inc. ClamVision® positioning software with depth sensors. Dredging operations in this area were also optimized following Best Management Practices and included two passes per arc to achieve design depth. Approximately 82 percent of the area achieved the target design elevation within a tolerance of ±6 inches. Approximately 93 percent of the area achieved the target depth within a tolerance of ±9 inches. Approximately 96 percent of the 15-foot MLW area achieved the target design elevation within a tolerance of ±12 inches (Table 5-7b; accuracy corrected for programming error and side slope).

- The 13-foot MLW area was dredged without the depth sensors. Approximately 66 percent of the area achieved the target design elevation within a tolerance of ±6 inches. Approximately 87 percent of the area achieved the target depth within a tolerance of ±9 inches. Approximately 97 percent of the 15-foot MLW area achieved the target design elevation within a tolerance of ±12 inches (Table 5-7b; accuracy corrected for programming error and side slope).
- The 11-foot MLW area was dredged both with and without the depth sensors. With the depth sensor, approximately 82 percent of the area achieved the target design elevation within a tolerance of ±6 inches. This accuracy increased to 93 percent within a tolerance of ±9 inches and 98 percent within a tolerance of ±12 inches (Table 5-7b; accuracy corrected for programming error and side slope).

This evaluation concludes that the dredging contractor was able to achieve 65-80 percent of the targeted elevations within the project's vertical tolerance of ±6 inches. The variance associated with achieving the targeted elevation is related to the presence or absence of operable depth sensor equipment. Overall, the days that the depth pressure sensors were operating correctly (compared to days when bucket depth was manually estimating using paint marking on the bucket chain) demonstrated an improvement in vertical dredging accuracy to achieve the target design elevation by approximately 8 to 13 percent.

The Pilot Study was designed to address production environmental dredging for bulk sediment removal rather than clean-up pass dredging of thin layers. Therefore, the accuracy results can be interpreted such that dredging projects executed in the Lower Passaic River (with similar water depths and cut depths) could be expected to achieve an accuracy of ±12 inches more than 90 percent of the time and ±6 inches more than 70 percent of the time. Operational production accuracy of ±12 inches may be improved if a heavier bucket weight is used with wire suspension systems, or if a fixed arm system is employed. Moreover, it should be recognized that as part of the NJDOT contract, penalties would be imposed on the dredging contractor if the deeper contaminated sediments were exposed. Consequently, the dredging contractor monitored the cut depth to prevent any overdredging, which led to underdredging to avoid penalties. This biased the vertical accuracy data and should be recognized as an artifact of the Pilot Study. However, efforts to minimize overdredging should be expected for a full-scale dredging operation, especially as the dredging operation approaches the targeted dredging depth.

6.0 MONITORING PROGRAMS

The following section describes the monitoring field programs implemented during the Pilot Study. Work was conducted in accordance with approved project plans (TAMS/ET and Malcolm Pirnie, Inc., 2005a), including the Work Plan, QAPP, and HASP. These plans and additional documents can be found on the public website www.ourpassaic.org.

6.1 HYDRODYNAMIC MONITORING PROGRAM

6.1.1 DESIGN OF THE HYDRODYNAMIC MONITORING PROGRAM

During the Pilot Study, an extensive monitoring program was designed to gather data to assess the impact of resuspension on the water column and the subsequent suspended sediment transport upflow and downflow of the dredging operation. The hydrodynamic monitoring program utilized a combination of six fixed moorings and two roving monitoring vessels. This monitoring program was designed based on the results of a modeling exercise conducted prior to execution of the Pilot Study (TAMS/ET, 2005). The six moorings were positioned within the river to provide a degree of redundancy in the event of equipment failure or other loss of data (Figure 6-1).[16] Near-field and paired far-field moorings, upriver and downriver of the Pilot Study Dredge Area, provide significant overlap for monitoring resuspension occurrences within the Lower Passaic River. Limitations with regard to the placement of the moorings were primarily affected by the dredging contractor's need to provide a safety zone between the active dredging and support operations and the optimal monitoring locations. Two additional sampling vessels were deployed to monitor water quality parameters throughout the Pilot Study Area.

[16] Loss of data at the moorings did not irreparably impact the overall evaluation of resuspension during dredging because the Pilot Study was designed to have redundant data. For example, the moorings are fixed points in space whereas the shipboard surveys are continuous and extend over a larger spatial area.

Moorings were installed as a part of the pre-dredging activities to provide adequate background data, and they were left in place until the post-dredging period had completed. With every remote sensing device, there is always a concern that the instrument may not perform properly or that data may be lost. Data from the moorings were not downloaded each day since dredging and monitoring of the resuspension were performed under shortened winter daylight conditions, and all crew members were involved with collecting water quality samples. Each mooring is quite heavy, and the removal of six moorings and download of the data would have severely delayed the start of each day's activities. Due to the overlap of the data provided through the positioning of each mooring location, these moorings were left undisturbed throughout the Pilot Study.

The hydrodynamic program was designed to accommodate potential loss of data by collecting redundant data. Loss of data did occur at a few mooring locations due to either a malfunction of equipment at some time during the dredging program or due to physical damage, which occurred at Mooring 3 after a barge that was being repositioned contacted the mooring. Loss of data did not irreparably impact the overall evaluation of resuspension during dredging because the program was designed to have redundant data. For example, the moorings are fixed points in space whereas the shipboard surveys are continuous and extend over a larger spatial area. The following damages or malfunctions occurred to instruments during the Pilot Study: the Acoustic Doppler Current Profiler (ADCP)[17] at the bottom of Mooring 3 malfunctioned; the Conductivity-Temperature-Depth (CTD) and Optical Backscatter Sensor (OBS) instruments at the bottom of Mooring 4 malfunctioned; Laser *In-Situ* Scattering and Transmissometry (LISST) from Mooring 3 operated sporadically; and the LISST data for part of December 6, 2005 on the *R/V Julia Miller* were corrupted.

[17] The ADCP is also known as an Acoustic Doppler Profiler.

6.1.2 PRELIMINARY MODELING

Positioning of the water column monitoring equipment was based on the modeling results of a three dimensional hydrodynamic and sediment transport model using Computational Fluid Dynamics (CFD) modeling software Flow3D (TAMS/ET, 2005).[18] This preliminary transport model was also developed to estimate the mass flux of sediment leaving the Pilot Study Dredge Area and to evaluate the impact of dredging on suspended sediment levels. The physical conditions that can influence the transport of sediments resuspended from dredging activities include the meandering geometry, tides, dynamic salt wedge, freshwater discharge, and sediments from the watershed transported by the river.

In the Pilot Study Area, the two main components that dominate the hydrodynamics are tidal energy and freshwater discharge. During the design phase of the project, the DREDGE model (Hayes and Je, 2000) was used to calculate the source strength and to provide estimates of the sediment that would be resuspended during dredging. Each sediment class (*i.e.*, sand, silt, and clay) was modeled as a group with an average median particle diameter (D_{50}). These rates were then used as source terms in the Flow3D model, which was used to simulate transport and settling of sediment. The dredging was assumed to occur for five days. The increase in sediment load was assumed to occur only during the 12-hour-per-day working period. Using a conservative approach, from a sediment transport perspective, effects of flocculation were not included and only the Stokes settling algorithm was used in the Flow3D model. By not including flocculation, the estimated mass flux leaving the system was conservative (biased high). Inclusion of flocculation could yield higher simulated settling velocities for the silts and clays, thus increasing settling rates and decreasing the estimate of the mass flux leaving the system. The model predicted that the suspended sediment plume would follow the path of deeper water conveyance (*i.e.*, along the navigational channel closer to the northern bank). The simulated plume is well-defined during ebb tide but becomes mixed after the flow reversal during flood tide. The plume progression characteristics were similar to those

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[18] Modeling software website: http://www.flow3d.com/ (last accessed on July 31, 2012).

observed during dye studies performed by Rutgers University in September and October 2004.

Assuming a one-percent sediment resuspension rate, the model predicted that dredging 5,000 cubic yards would result in the resuspension of 55 tons of sediment. Sand is 16 percent of the 55 tons by weight, and it was expected to settle within approximately 500 feet of release. Therefore, based on the preliminary model, an estimated 46 tons of silt and clay would leave the site at the proposed dredging volume. During the Pilot Study, approximately 4,000 cubic yards of dredged material were removed, or 80 percent of the proposed volume. Scaling the model-predicted sediment resuspension to the actual dredged volume yields an estimated resuspension of 44 tons of sediment. Based on the 16 percent sand fraction settling, this calculation suggests that approximately 37 tons (or approximately 7 tons per day) of resuspended silts and clays would leave the Pilot Study Area during operation. The resuspension of 7 tons per day would be equivalent to approximately 10 percent of the natural daily average sediment load in December 2005 (approximately 70 tons). Figure 6-2 shows the estimated sediment resuspended from dredging based on the modeling results as compared to the daily average natural loads in the Lower Passaic River.

6.1.3 MOORING DEPLOYMENT AND RETRIEVAL

The hydrodynamic program consisted of six fixed moorings: three moorings were positioned on one side of the dredging operation and the other three moorings were positioned on the other side (Figure 6-1). Moorings 1, 2, and 3 were on the upflow side of the dredging operation during an ebb tide (river flow towards Newark Bay) while Moorings 4, 5, and 6 were on the downflow side. This relationship was reversed during a flood tide. Four of the six moorings (Moorings 2, 3, 4, and 5) are located along the centerline of the Pilot Study Dredge Area. Based on model predictions that the plume would follow the path of deeper water conveyance, the remaining two moorings (Moorings 1 and 6) were located in the deepest portion of the navigation channel at the same distance (at approximately 1,000 feet) as the outermost centerline moorings (Moorings 2 and 5).

On each side of the dredging operation, the moorings were arranged in two transects. The inner transect (closest to the dredging operation) was positioned at a distance of approximately 400 feet. This inner transect corresponds to the minimum distance that the monitoring equipment can safely operate while allowing for movement and turning of the dredge, guide barge, and hopper barges. Monitoring at the inner transect is referred to as "near-field monitoring." The outer transect was positioned at a distance of approximately 1,000 feet from the Pilot Study Dredge Area. Monitoring at the outer transect is referred to as "far-field monitoring." Based on the settling rates of the coarse particles (*i.e.*, sand) most of this material is expected to settle before reaching the near-field monitoring. Therefore, primarily the fines (*i.e.*, silt and clay particles) will be monitored between the near-field and far-field monitoring locations.

A mooring consisted of a float at the water surface and an anchor and a tripod frame suspended on a chain (Figure 6-3). The anchor and the tripod frame rested on the river bottom while the float marked the mooring location at the surface. Each mooring was equipped with two CTD and OBS probes and ADCP sensor. In addition, the two centerline moorings closest to the Pilot Study Dredge Area (Moorings 3 and 4) were each equipped with a LISST probe (model LISST-100 Type C). These instruments are able to record volume concentrations of particles in 32 bin sizes between 2.5 and 500 microns. The moorings monitored water column stratification and stability, particle concentration, and size distribution on a 24-hour-basis throughout the project. Table 6-1 shows the measurements made by the instruments on each mooring. Table 6-2 shows the instrument identification numbers, frequency of recording, and number of data records for each instrument.

The mooring equipment and instruments were assembled at the Coastal Ocean Observation Laboratory in the Institute of Marine and Coastal Sciences building at Rutgers University in New Brunswick, New Jersey. They were brought to the PVSC dock in Newark, New Jersey on December 1, 2005 and carried to the Pilot Study Area aboard the *R/V Caleta*, owned by Rutgers University. Each mooring assembly was deployed and positioned at the previously selected locations using a differential global positioning system (DGPS). The instruments mounted on these moorings started collecting data on December 1, 2005, four days before dredging operations commenced. Water quality monitoring was completed on December 12, 2005, and each mooring assembly was carefully retrieved from the Pilot Study Area by the *R/V Caleta*, and brought back to the PVSC dock. From the PVSC dock, the moorings and the associated instruments were taken to the Coastal Ocean Observation Laboratory at Rutgers University in New Brunswick, and the data were downloaded for further processing. As described in greater detail in Appendix G, Rutgers University also performed calibration of the ADCP acoustic backscatter results and the turbidity values measured by the OBS. Calibration was performed by using the validated results of total suspended solids (TSS) shipboard sampling provided by DESA. Refer to Appendix G for uncertainty measurements on the TSS measurements.

6.1.4 SHIPBOARD SURVEY PROCEDURES

Two vessels were utilized to perform shipboard surveys (the *R/V Caleta* and *R/V Julia Miller*). The *R/V Caleta*, which was equipped with a GPS, CTD probe, OBS, and ADCP, conducted sweeps of the near-field resuspension plume in a zigzag pattern, crossing the plume approximately seven times in approximately one hour (refer to boat icons labeled "M" on Figure 6-4). The *R/V Caleta* was also equipped with on-board laptop computers that allowed for the real time collection and display of the velocities, acoustic backscatter, salinity, pressure, and temperature over the depth of the water column. Approximately 100 grab samples for analysis of TSS were collected by the *R/V Caleta* throughout the five-day Pilot Study to calibrate the direct reading instruments. Two different measurement techniques were utilized: a continuous monitoring technique using the towed ADCP and a discrete water column profiling technique using the CTD probe and OBS. The ADCP measurements were recorded continuously, and at selected intervals and locations, CTD probe casts were made to obtain complete vertical profiles of the water column.

The *R/V Julia Miller* was equipped with GPS, CTD probe, LISST, and OBS. On-board laptop computers allowed for the real time collection and display of the particle size distribution, turbidity, salinity, pressure, and temperature (refer to boat icons labeled "L" on Figure 6-4). Discrete measurements were recorded at selected locations and intervals with the LISST, OBS, and CTD probe to obtain a complete vertical profile of the water column. During most of its deployment, the *R/V Julia Miller* ran along the centerline of the plume parallel to the flow, but for a limited time, this vessel also moved in a zigzag pattern to identify the edges of the plume. Both the *R/V Caleta* and *R/V Julia Miller* shifted their operation with the tides and also monitored upflow of the dredging operation to measure and record background conditions.

The *R/V Caleta* conducted daily shipboard surveys on December 5, 2005 through December 8, 2005 and on December 10, 2005 during the daylight hours. No surveys were performed on December 9, 2005 since there was no dredging due to a severe snowstorm with gale force winds. The *R/V Julia Miller* conducted daily shipboard surveys on December 5, 2005 through December 8, 2005 during the daylight hours, but did not perform any surveys on Saturday, December 10, 2005. Rutgers University planned to deploy the LISST from the *R/V Julia Miller* onto the *R/V Caleta* on December 10, 2005; however, one of the instrument cables was damaged early that day, and the instrument was not usable.

6.2 WATER QUALITY MONITORING PROGRAM

6.2.1 DESIGN OF THE WATER QUALITY MONITORING PROGRAM

Sampling on the Trace Organic Platform Sampler (TOPS) vessels was continuous in an attempt to collect samples during as many ebb and flood tides as possible within the dredging window. Each vessel was equipped with a GPS, a depth profiler, a peristaltic pump, a TOPS apparatus, and two ISCO automatic samplers. The Malcolm Pirnie, Inc. vessel served as the upriver TOPS boat (TU) and performed continuous traverses along upriver far-field monitoring moorings (Moorings 1 and 2). A vessel deployed by Aqua Survey, Inc., the *R/V Delaware*, served as the downriver TOPS boat (TD) and performed continuous traverses along the downriver far-field monitoring moorings (Moorings 5 and 6) (refer to boat icons labeled “T” on Figure 6-4).

Water quality monitoring using TOPS equipment occurred prior to dredging operation on December 1, 2005, during dredging operations, and after dredging on December 12, 2005. As part of the TOPS monitoring program described in the Work Plan, one integrated TOPS sample was collected from each TOPS boat (TU and TD) on December 1, 2005 prior to dredging activities. Two integrated TOPS samples were collected from each TOPS boat (TU and TD) on December 5-6, 2005 and December 10, 2005. Due to tide conditions and available daylight, one integrated TOPS sample was collected from each TOPS boat (TU and TD) on December 7-8, 2005. Following dredging operations, on December 12, 2005, only one TOPS boat was operating at the downriver far-field monitoring location (near Moorings 5 and 6), and only one TD sample was collected as described in the Work Plan.

Monitoring consisted of round-trip traverses at half-hour intervals along the upriver and downriver transects perpendicular to the river flow. During the ‘A’ leg of the traverse from the south river bank to the north river bank, the water intake lines were positioned 3.3 feet (or 1 meter) below the water surface. During the ‘B’ leg of the traverse from the north river bank to the south river bank, the water intake lines were positioned 3.3 feet (or 1 meter) above the sediment bottom. No samples were collected near the edges of the river where water depths were less than 6 feet. The raising and lowering of the water intake lines with a weighted fish was performed using a manually operated winch system custom-designed by the Water Resources Division of USGS for each vessel. The duration of each round trip traverse was kept as constant as possible at 10-12 minutes throughout the ebb or flood tide that was occurring during active dredging activity.

Water samples were collected by these vessels for analysis of TSS, particulate and dissolved organic carbon (POC and DOC), chloride/bromide, dissolved and total metal and mercury concentrations, PCDD/F congeners, PCB congeners, and pesticides. During an ebb tide, the sediment load can be evaluated by comparing TSS and contaminant concentrations measured downriver to background TSS and contaminant concentrations measured upriver. Similarly, during a flood tide, the sediment load can be evaluated by comparing TSS and contaminant concentrations measured upriver to background TSS and contaminant concentrations measured downriver.

6.2.2 Collection of Organic Parameters

The chemical samples represent integrated composite samples (consisting of six or seven traverses) that provide average contaminant concentrations on suspended sediment across the channel for the entire duration of sampling. The TOPS samples consisted of residue on glass fiber filters (GFF) used to collect samples for suspended-phase contaminants and exposed XAD-2 polystyrene exchange resin (XAD) cartridges for dissolved organics analysis. Water was pumped through dedicated Teflon lines and then through a pre-cleaned (baked) canister GFF that collected suspended sediments. The outlet from the canister filter was then split and a small portion pulled through a GFF and then through two XAD cartridges. The outlet water from the GFF and XAD cartridges was collected in separate carboys, and the volume of the processed water was measured using a graduated cylinder at the conclusion of the sampling. The sediment-laden GFF and the XAD cartridges were sent for analysis of PCB congeners, PCDD/F congeners, and pesticides. Because the primary focus of the monitoring program was on particle-borne contaminants, only a limited number of XAD cartridges from selected days were analyzed.[19] As stated previously, the ISCO samples were used to estimate the average cross-sectional suspended sediment and POC content in the surface and bottom water. Because they were collected concurrently with the TOPS composite sample, they also provide the means to calculate the mass of sediment captured on the GFF - a required input for converting the results of the laboratory analyses into concentrations (Table 6-3).

[19] In total, 19 GFF samples and 9 XAD samples were analyzed following the *Final Project Plans for Environmental Dredging Pilot Study* (TAMS and Malcolm Pirnie, Inc., 2005b). One extra dissolved sample was collected and analyzed.

Below freezing temperatures were common throughout the Pilot Study. Each evening the TOPS boat crews would thoroughly drain the sampling tubing and stow them out of the elements. Aboard the *R/V Delaware* each morning, the crew would thaw tubing with heavy duty pistol style electric heaters. The heated cabin held most of the sampling tubing, which prevented the tubing from freezing for the remainder of the day. Aboard the Malcolm Pirnie, Inc. vessel, electric heaters were used as needed throughout the day since all equipment aboard was exposed to the elements. In the evening, a plastic curtain was unfurled to keep snow and ice off the equipment.

An important consideration in this type of chemical sampling, where results from different locations and times are to be compared, is that similar masses and volumes are processed in each sample so that similar (low) detection levels are obtained in the analytical methods. In this type of sampling, the mass of sediment collected on the filters is not known until well after sampling has ended, so volumes and pumping rates were chosen to increase the likelihood of comparability and sufficient sensitivity. The masses and volumes that were ultimately processed in this work (Table 6-3) were similar for each pair of samples, and were sufficient to allow low-level resolution of the compounds of interest in all samples. A summary of the minimum, maximum, and average sample-specific detection limits for the general classes of compounds measured in this Pilot Study is presented in Table 6-4. Note that detection levels are sample-specific and compound specific [*i.e.*, each sample and each compound (including each PCB congener) has a unique level of detection that is based on the analytical methods, the measuring instrument, and the mass of the sediment sample or volume of the aqueous sample available]. The similar water volumes and sediment sample masses obtained also show that very consistent sampling methods were employed at both upriver and downriver far-field monitoring transects. This sampling program is discussed in further detail in Appendix H.

6.2.3 Collection of Inorganic Parameters

In addition, each TOPS boat was equipped with two ISCO automatic samplers that were utilized to collect samples for TSS, TOC, POC, and chloride/bromide analyses. During the ‘A’ leg of the traverse from the south river bank to the north river bank, one sample was collected from the ISCO sampler for analysis of TSS, and a second sample was collected for analysis of POC. This process was repeated during the ‘B’ leg. These samples were used to estimate the average cross-sectional suspended sediments and POC content in the surface and bottom water. A peristaltic pump on each TOPS boat was used to collect dissolved and total metals plus low-level mercury samples. However, instead of sample collection occurring on each traverse of the river, samples were collected as half-day composites [composited from (nominally) seven traverses at half-hour intervals over a 3-hour period]. Samples were prepared by collecting approximately equal aliquots of river water into two sample bottles on each leg of the traverse. By splitting the pump outflow of this line, both dissolved and total metal samples were collected. Multiple sample intake tubing lines were ganged together so that samples would be collected from the same depth while using different pumping systems. The intake tubing for the low-level mercury samples was placed slightly below that of the others tubing lines so as to comply with the “clean hands” sampling protocol.

6.2.4 Sample Processing

Samples were transferred periodically from the sampling vessels to the designated processing area. Initially, processing was accomplished in a shed at the PVSC dock at the head of Newark Bay. Soon after the program started, however, this operation was moved to the USACE vessel *SUV Hudson* stationed downriver of the monitoring activities. Each sample bottle was identified by the sampling crew using indelible marker, and sample batches were accompanied by field log notes indicating the corresponding planned sampling times. The samples were processed by attaching labels and packaging them in coolers using double bagged ice and bubble wrap. Prior to labeling the ISCO samples, the TSS duplicate samples were chosen. The sample labels contained the sample identification, the planned sampling date and time, required analysis, sampler initials, bottle number, and contact number.

The sample identification contained the information on the sampling vessel, analysis, depth, date, and planned sampling time (plus or minus 1200 for the duplicate samples).

For instance, sample TU-TSA-051201-1430 refers to a TSS sample collected by the Upriver TOPS boat (TU) from the ‘A’ leg of the traverse (TSA) on December 1, 2005 between 1430 hours EST and 1500 hours EST. The corresponding duplicate was designated as TU-TSA-051201-0230. The sample identifications were entered into the FORMS II Lite database, and separate Traffic Reports (or chain of custody forms) were prepared each day for samples designated for low-level mercury, TSS, TAL metals, and TOC.

6.2.5 SAMPLE SHIPMENT

A label was immediately placed on the samples designated for low-level mercury analysis, and these mercury samples were shipped for express overnight delivery to Severn Trent Laboratory in North Canton, Ohio (STL-OH). Samples collected in the morning for TAL metals analysis were generally labeled and packaged for shipment the same day. ISCO samples were processed for shipment the next sampling day. These samples (plus any samples collected for TAL metals analysis and not shipped that day) were stored in coolers with double bagged ice. The coolers were then tagged with custody seals and locked within the field processing shed on the PVSC dock overnight.

Except for a few instances described below, the TAL metals and ISCO samples were picked up by a USGS courier and taken to the USGS Laboratory in West Trenton, New Jersey. The TSS and TAL metals samples were then shipped to DESA without further preparation. Samples selected for organic carbon analysis were filtered at the USGS Laboratory (three 60-milliliter volumes were filtered for each sample). The filters, which represent the suspended-phase organic carbon or POC, were then shipped to DESA where they were analyzed. Each set of three filters was submitted as a single sample to DESA; two samples were analyzed (the third was backup), the results were averaged, and the relative percent difference (RPD) was calculated by DESA. In some instances, the samples that were picked up by the USGS courier were not delivered to the DESA laboratory in a timely manner, and subsequently, the analytical holding times were exceeded (at most by 12 days). These samples included bromide, chloride, POC, and TOC. However, even though the samples exceeded their holding times, the samples were validated by the DESA laboratory, and none of the samples were rejected. Therefore, the holding time exceedance did not impact the validity of the data.

Routine procedures deviated in the following instances:

- The pre-dredge TSS and TAL metals samples were processed at the USGS Laboratory and shipped by a TAMS/ET courier to DESA on December 2, 2005.
- The sampling conducted by the downriver TOPS boat during the afternoon of December 6, 2005 did not yield enough sample volume for the TAL metals analysis. Therefore, sample volume in excess of what was necessary for the low-level mercury sample was salvaged and shipped by STL-OH to the DESA laboratory for TAL metals analysis.
- The ISCO and TAL metals samples from the last day of sampling (December 12, 2005) were picked up by a TAMS/ET courier; samples for TSS and TAL metals analyses were delivered directly to DESA while samples for TOC analysis were delivered to the USGS Laboratory for filtering and subsequent shipment to DESA.

Since a CLP laboratory was not designated until the end of the Pilot Study sampling program, the GFF and XAD samples were not shipped immediately. These samples were stored in a refrigerator in the locked field shed at the PVSC dock until being shipped on December 13, 2005 to Axys Analytical Services (Sidney, British Columbia, Canada), the assigned CLP laboratory.

Laboratories were requested to report only what they actually analyzed. As a result, the results for DOC were reported in units of "milligrams per filter," and the organic data were reported as "nanograms [or picograms] per sample." These raw or primary data have subsequently been used by the project team to develop derived quantities using data from other sources (*e.g.*, volume of water passing through the GFF or XAD samples) to convert results to units of nanograms of contaminant per liter of water (ng/L), and using the TSS data or the volume filtered by USGS to convert the DESA TOC data from analysis of the filters to milligrams of carbon per gram of solids (mg C/g) and milligrams of carbon per liter of water (mg C/L).

6.3 DATABASE ASSEMBLY

The data collected as part of the resuspension monitoring program of the Pilot Study have been assembled by TAMS/ET into two separate databases using Microsoft (MS) Access software: a hydrodynamics monitoring database and a water quality monitoring database. The primary purpose of assembling these databases is to make all of the data available to the public, partner agencies, and Pilot Study team members in a portable format that is both user-friendly and easily readable. Further, it makes the Pilot Study data readily available to other members of the Study for purposes such as hydrodynamic modeling and the Feasibility Study. The common fields in both databases are the date and time.

6.3.1 HYDRODYNAMICS MONITORING DATABASE

The hydrodynamics monitoring database is provided in electronic format in Appendix I. It includes the data collected by the various instruments (listed on Table 6-2) that were mounted on the six fixed moorings as well as those that were on the two monitoring vessels, the *R/V Caleta* and the *R/V Julia Miller*. A data dictionary that describes the contents of all of the typical data fields for all of the instruments in this database is also available in Appendix I.

Depending on the frequency of recording the data, the number of measurements reported varied by instrument. For example, for the ADCP mounted at the bottom of the fixed moorings, the number of data records ranged from approximately 500 for Mooring 1 to nearly 16,000 for Mooring 6. Nearly 18,000 records exist for the ADCP on the *R/V Caleta*. These records include along-channel, cross-channel, and vertical velocities, and acoustic reflectivity in up to 32 bin sizes. As described in Appendix G, a calibration was performed using corresponding TSS analyses generated by DESA to convert the reflectivity values into TSS readings. The database contains the calibrated TSS values. Similarly, for the LISST deployed on the *R/V Julia Miller*, there are nearly 25,000 data records, and each data record contains particle volume concentrations in 32 bin sizes. All of the original data was recorded by Rutgers University in Greenwich Mean Time (GMT) and was converted by TAMS/ET to EST. The x-y coordinates of the moorings and the vessels were originally recorded as latitude/longitude and were converted to New Jersey State Plane Coordinates. The x-y coordinates are available in the database in both formats.

Once the MS Access database was finalized, the tabulated data were compared with formatted versions (or, where possible, raw data versions) of the original instrument data source files. This comparison was done in order to establish that no errors were made in the translation/transfer of data. This database does not include any data for the ADCP at the bottom of Mooring 3 or the CTD and OBS probes at the bottom of Mooring 4 because, upon retrieval, it was determined that they had malfunctioned. The database also does not include some bad or corrupted data for part of December 6, 2005 from the LISST that was deployed on the *R/V Julia Miller*. Limited LISST data are available from Mooring 3 since the instrument operated sporadically.

6.3.2 WATER QUALITY MONITORING DATABASE

The water quality monitoring database along with a data dictionary is provided in electronic format in Appendix I. Analytical results (from the ISCO and TOPS samples) are also presented in a series of tables that are included in Appendix J. Data generated from the water quality monitoring program are validated.

As the analytical data were received from the various laboratories, they were entered into a MS Access database. Any inconsistencies that had to be resolved before entering the data were noted in the comment field of the database. For instance, the results for the sample TU-OCB-051206-0930 were received back with the identification label TU-OCB-051206-930. This problem was corrected and noted in the comments field. The analytical results were paired with the information available from the field logs of the three sampling vessels (the *R/V Julia Miller* did not collect any samples). The information extracted from the field logs includes the sampling times, sample depths, and collection problems/concerns (*e.g.*, if the vessel stalled or the lines froze). The XAD cartridge numbers were also determined from the field logs. Both the field processing logs and the sampling vessel logs were used when entering the field bottle numbers of each ISCO sample. The corresponding shipment dates, shipment methods, and traffic report numbers were entered based on the FORMS II Lite database. Duplicates were designated, and final sample identification was assigned for all the samples such that samples collected at the same sampling location and time could be easily grouped. The final sample identification used nomenclature such that information regarding the vessel, date, time, and depth is readily discernable.

As specified, the POC data provided by DESA contained two replicate analyses as well as the average and RPD. Only the average values were retained in the final database since the RPD values were used by DESA in determining the usability of the data. The analytical data for the GFF and XAD samples were originally received as mass per sample. Using the flow rates measured by the instruments and sampling personnel, the GFF and XAD values were converted to the conventional units of mass per volume.

6.4 DEVIATIONS FROM WORK PLAN ON MONITORING PROGRAMS

Deviations from the Work Plan were reported for the monitoring programs during the Pilot Study. For the hydrodynamic monitoring program, the *R/V Julia Miller* did not perform any surveys on December 10, 2005. Rutgers University moved the LISST from the *R/V Julia Miller* to the *R/V Caleta* for monitoring activities scheduled on December 10, 2005. However, one of the instrument cables on that LISST was damaged early that day, and the instrument was unusable. Additional Work Plan deviations were reported for the water quality program sample collection and analysis. Since a CLP laboratory was not designated until the end of the Pilot Study sampling program, the GFF and XAD samples were not shipped immediately. These samples were stored in a refrigerator in the locked field shed at the PVSC dock until being shipped on December 13, 2005 to Axys Analytical Services (Sidney, British Columbia, Canada), the assigned CLP laboratory. This shipment procedure was also a deviation from the Work Plan.

7.0 COLLECTED MONITORING DATA

The following sections presents the data collected during the hydrodynamic and water quality monitoring programs that were implemented during the Pilot Study. An evaluation of these data and estimates of net suspended sediment fluxes are presented in Section 8.0.

7.1 HYDRODYNAMICS MONITORING DATA

7.1.1 FLOWS AND TIDAL CYCLES

The two main hydrodynamic forces dominating the Pilot Study Area are freshwater discharge and tidal energy. Figure 7-1 shows the freshwater discharge as recorded at the USGS gauge in Little Falls, New Jersey between November 20, 2005 and December 20, 2005. Note that the flows at the Dundee Dam are typically 10 percent higher than at Little Falls.

Before the Pilot Study began, freshwater discharge peaked at 4,300 ft^3/s or [120 cubic meters per second (m^3/s)] on December 1, 2005, and then began to decrease to approximately 1,100 ft^3/s (31 m^3/s) on December 14, 2005. A precipitation event on December 15, 2005 produced a second discharge peak of 4,500 ft^3/s (130 m^3/s) on December 19, 2005. The dredging was performed between December 5, 2005 and December 10, 2005, and during this period the freshwater discharge ranged from 1,800 ft^3/s (51 m^3/s) to 3,100 ft^3/s (88 m^3/s). This range of freshwater discharge is higher than the mean December freshwater discharge of 1,300 ft^3/s (37 m^3/s) and the annual freshwater discharge of 1,100 ft^3/s (31 m^3/s) as reported at the USGS gauging station at Little Falls, New Jersey. However, this freshwater discharge range is not uncommon for the Lower Passaic River since there is approximately a 1-in-4 chance of freshwater discharge exceeding 1,800 ft^3/s (51 m^3/s)in December (which corresponds to flows observed on December 5-7, 2005 during the Pilot Study).

The mean sea level recorded by NOAA at the Bergen Point West Reach station between November 20, 2005 and December 20, 2005 is shown on Figure 7-2. The sea level record shows both the variability associated with the spring tide/neap tide cycle as well as strong variability associated with meteorological forcing. Between November 20, 2005 and December 20, 2005, the tidal range peaked at 6.8 feet just before the start of the dredging, decreased during the week of the Pilot Study, and peaked to 6.4 feet again at the end of the dredging. On December 9, 2005, a strong wind event drove the sea level downward resulting in a lowering of the evening high tide, which in turn produced the lowest sea level over this record during the subsequent low tide. Water surface elevations measured at Mooring 2 during the period from December 4-10, 2005 are presented in Figure 7-3. This figure also shows the periods during which dredging was being performed (magenta bands) along with the times for all the high and low tides. The storm event on December 9, 2005 is also observed on this plot from the relatively low elevation during the flood tide.

7.1.2 ADCP AND CTD MOORING DATA

The ADCP instruments on Moorings 1, 2, 4, 5, and 6 were calibrated using a regression between the acoustic backscatter from the ADCP on the *R/V Caleta* and the acoustic backscatter from the Sontek ADCP and RD Instrument (Teledyne) ADCP on the moorings (Figure 7-4). As stated previously (Section 6.1.1), the ADCP at the bottom of Mooring 3 and the CTD and OBS probes at the bottom of Mooring 4 were faulty, and therefore, no data are available for these moorings. The OBS on the *R/V Caleta* and *R/V Julia Miller* were calibrated first using a regression between the turbidity and the TSS data obtained from the approximately 100 grab samples. This calibration was then applied to the moored OBS to obtain a time series of TSS. Refer to Appendix G for further detail on the calibration procedure and uncertainty measurements.

The results from the ADCP and CTD probe for Moorings 1, 2, 4, 5, and 6 are presented in supplemental figures in Appendix K (refer to Figure 6-1 for the positions of the moorings relative to the dredging operations). These supplemental figures show:

- The estimated suspended sediment concentrations based on the ADCP measurements as a function of depth and time.
- The along-channel velocity as a function of depth and time.
- A time-series of depth-averaged TSS based on the ADCP measurements and velocity.
- Salinity and temperature information as recorded by the CTD probe.

A summary of the data from Mooring 1 (located upriver of the dredging operation) is presented in tabulated form (Box A) to assist the reader in the interpretation of the supplemental figures for the other moorings.

Box A: Observations in the ADCP and CTD Probe Data Collected at Mooring 1

Date[a]	Dredging Operation	Observations in Mooring Data[b]
December 1-2, 2005	Pre-dredge Monitoring	- Velocities were the highest during ebb tide. - Observed the estuarine turbidity maxima. - Observed movement of salt wedge.
December 2-4, 2005	Pre-dredge Monitoring	- Maximum depth-averaged TSS is slightly lower than the values recorded on December 1-2, 2005 while maximum depth-averaged velocities are comparable. - During morning flood tide on December 4, 2005, the surface salinity is equal to the bottom salinity.
December 4-6, 2005	Dredge 11-foot MLW cut and 13-foot MLW cut	- Observed the estuarine turbidity maxima. - Highest TSS values during December 4-6, 2005 are less than the pre-dredge TSS values reported on December 2, 2005. - The highest depth-averaged velocities on December 4-6, 2005 are lower than the pre-dredge velocities on December 2, 2005. - Salinity values on December 4-6, 2005 are similar to pre-dredging on December 2, 2005.
December 6-8, 2005	Dredge 15-foot MLW cut	- Relatively low TSS values reported despite dredging. - Highest depth-averaged TSS values recorded on December 6-8, 2005 are lower than those TSS values recorded during dredging on December 4-6, 2005 while depth-averaged velocities are comparable during the two dredge periods. - Salinity values on December 6-8, 2005 are similar to pre-dredging on December 2, 2005.

Box A (continued)		
Date[a]	Dredging Operation	Observations in Mooring Data[b]
December 9-10, 2005	Snowstorm on December 9, 2005. Dredge 15-foot MLW cut on December 10, 2005	- Winds from the storm on December 9, 2005 caused a lowering of the high tide and low tide. - Highest velocities were recorded on the ebb tide on December 9, 2005. - Highest depth-averaged TSS values and depth-averaged velocities were recorded on the evening of December 9, 2005 when no dredging activities were occurring. - Highest salinity values since December 2, 2005 are recorded.
December 10-11, 2005	Post-dredge Monitoring	- Depth-averaged TSS values and depth averaged velocities recorded during the post-dredge monitoring are lower than values reported on December 2, 2005. - Salinity is comparable to the highest salinity values recorded since December 2, 2005.

a: Dates correspond to midnight of the first date listed to midnight of the last date listed.
b: Estimated TSS concentrations based on the ADCP measurements.

7.1.3 LISST Mooring Data

The particle distribution upflow and downflow of the dredging operation can be evaluated by comparing the two innermost LISST probes (Moorings 3 and 4)[20]. Particle size concentrations from December 4-12, 2005 from Moorings 3 and 4 are presented in Figures 7-5 through 7-13. In each figure, particle size concentration is grouped into three size ranges: less than 10 microns, 10 to 100 microns, and greater than 100 microns. Time intervals for the ebb and flood tides are also marked on the figures. Table 7-1 supplements these figures and shows the median particle size for each size class (or bin) with units of microliters per liter of water (μL/L). The larger particle sizes identified in the higher bins represent flocculated particles rather than larger grain size particles (*e.g.*, sands). Refer to Section 8.2 for further evaluation of the LISST data using principal component analysis, which indicates that the variability in the LISST data prevents a distinguishing of the upflow and downflow locations and the impacts of dredging on resuspension.

[20] The LISST data at Mooring 3 were sporadically recorded due to the malfunctioning of the instrument; when Mooring 3 was not operating correctly, a comparison of data was not possible.

A comparison of upflow and downflow particle size concentrations was not possible during the pre-dredge monitoring period (Figure 7-5) because Mooring 3 sporadically recorded data on December 4, 2005. Similar recording malfunctions on Mooring 3 also occurred on the first day of dredging (December 5, 2005; Figure 7-6). However, between 0430 hours EST and 0700 hours EST during flood tide on December 5, 2005 (when the LISST on Mooring 3 did record data), no dredging was performed and the data from Mooring 4 (upflow) appears to be very similar to the data from Mooring 3 (downflow). The bulk of the dredging on December 5, 2005 occurred during ebb tide (1030 hours EST and 1730 hours EST) when Mooring 4 was downflow of the dredging operation. The particle size concentrations recorded at Mooring 4 were higher than those concentrations recorded at Mooring 3 (upflow).

The second day of dredging occurred on December 6, 2005 with the execution of the 11-foot MLW cut (Figure 7-7). During flood tide (0930 hours EST and 1200 hours EST), the particle size concentrations recorded on Mooring 4 (upflow) are higher than those concentrations recorded at Mooring 3 (downflow). The remainder of the dredging on December 6, 2005 was performed during ebb tide (1200 hours EST and 1900 hours EST) when Mooring 4 was downflow of the dredging operation. The particle size concentrations recorded at Mooring 4 are higher than those concentrations at Mooring 3 (upflow). However, a similar pattern of higher particles concentrations on the downflow of the Pilot Study Area is also observed on December 6, 2005 earlier in the day (2400 hours EST to 0530 hours EST) when dredging operations were not occurring.

On December 7, 2005, dredging operations began to construct the 15-foot MLW cut. The first part of the dredging was performed during a flood tide between 0830 hours EST and 1200 hours EST when Mooring 3 was downflow of the dredging operation (Figure 7-8). Between 0800 hours EST and 1030 hours EST, the particle size concentration both upflow and downflow of the dredging operations are about the same value. The second part of the dredging was performed during an ebb tide between 1200 hours EST and 1600 hours EST when Mooring 4 as downflow of the dredging operation. Particle size concentrations downflow of the dredging operation were higher than those concentrations recorded upflow, especially for the larger particles. After 2000 hours EST after the tide change, the particle size concentrations at Moorings 3 and 4 were about the same value.

Construction of the 15-foot MLW cut continued on December 8, 2005. Between 0200 hours EST and 0800 hours EST (ebb tide), no dredging was performed, and the particle size concentration both upflow and downflow of the dredging operations are similar (Figure 7-9). Dredging was mainly performed during the flood tide between 0930 hours EST and 1330 hours EST. The particle size concentrations recorded at Mooring 4 (upflow) were higher than those concentrations recorded at Mooring 3 (downflow). Note that unusual spikes in particles were observed at Moorings 3 and 4; currently there is no explanation as to why this spike occurred. After dredging activities ceased for the day, the particle size concentrations both upflow and downflow of the dredging operations are about the same value.

No dredging occurred on December 9, 2005 due to inclement weather. Particle size concentrations on this day are provided in Figure 7-10. Construction of the 15-foot MLW cut continued on December 10, 2005 (Figure 7-11); however, a comparison of upflow and downflow particle size concentrations was not possible because Mooring 3 sporadically recorded data. The particle size concentrations during the post-dredging monitoring are provided in Figures 7-12 and 7-13. During the early morning flood tide on December 11, 2005 (2400 hours EST to 0500 hours EST) and the ebb tide (0500 hours EST and 1000 hours EST), the particle size concentration patterns recorded at Moorings 3 and 4 were dissimilar. However, for the remainder of the day on December 11, 2005, particle size concentrations were about the same value.

Overall, the variability in the LISST data prevents the distinction of the upflow and downflow locations and the impacts of dredging on resuspension. Refer to Section 8.2 for further evaluation of the LISST data collected at the moorings and on the *R/V Julia Miller*. The LISST data from casts performed from the *R/V Julia Miller* are also presented in supplemental figures in Appendix K. These figures show the particle distribution on the upriver and downriver side of the dredging operation during different tidal cycles.

7.1.4 SHIPBOARD SURVEY DATA

In addition to the mooring data, the *R/V Caleta* collected shipboard survey data using the CTD probe, OBS, and ADCP instruments. The ADCP data from the *R/V Caleta*, including along-channel velocities and TSS (as computed by the surrogate measured by the ADCP), are presented in supplemental figures in Appendix K along with the multiple ship tracks for the vessel. A summary of select data collected on the *R/V Caleta* during these multiple passes is presented in tabulated form (Box B) to assist the reader in the interpretation of the supplemental figures. Note that additional data evaluations on the along-channel velocities and TSS collected by the *R/V Caleta* are presented in Appendix G as part of a suspended sediment flux evaluation.

Box B: Along-Channel Velocities and TSS Data Collected on the R/V *Caleta*

Date	Dredging Operation	Observations in Mooring Data[a]
December 5, 2005 (upflow)	Dredge 13-foot MLW cut	- Higher velocities observed at the surface (ebb tide). - Little variation in the TSS concentrations.
December 5, 2005 (downflow)	Dredge 13-foot MLW cut	- Higher velocities observed at the surface (ebb tide). - Zigzag movement of vessel observed in velocity data. - Higher TSS values observed at deeper depths, especially closer to the southern bank of the river.
December 6, 2005 (upflow)	Dredge 11-foot MLW cut	- High velocities observed at all depths due to the strong ebb tide. - Higher TSS values observed at deeper depths, especially closer to the southern bank of the river.
December 6, 2005 (downflow)	Dredge 11-foot MLW cut	- Higher velocities are observed in the deeper channel while TSS values are not observed. - TSS is observed in the southern area of the channel due to the lower velocities in the shallower areas.
December 7, 2005 (upflow)	Dredge 15-foot MLW cut	- Relatively low velocities observed (flood tide). - Relatively low TSS values observed.
December 7, 2005 (downflow)	Dredge 15-foot MLW cut	- Relatively low velocities observed (flood tide). - Relatively low TSS values observed.
December 8, 2005 (upflow)	Dredge 15-foot MLW cut	- Higher velocities observed along northern bank. - Higher TSS values observed at deeper depths.

a: Estimated TSS concentrations based on the ADCP measurements.

7.2 WATER QUALITY MONITORING DATA

7.2.1 WATER QUALITY DATA USABILITY

The following section summarizes the data collected during the water quality monitoring program and provides an assessment of the overall confidence and usability of the data. Refer to Table 7-2 and Table 7-3 for a summary of the parameters and quantities of samples generated during the program.

For the organic analyses collected with the TOPS instrument, the GFF samples are considered to represent the suspended-phase. Since the primary focus of the Pilot Study was to evaluate the impacts of dredging and the resuspended sediments, a greater number of GFF samples (19) were analyzed as compared to the XAD cartridges (9), which represent the dissolved-phase. Refer to Appendix H for discussion on dissolved-phase concentrations. The details of the extraction procedure are presented in the QAPP (TAMS/ET and Malcolm Pirnie, Inc., 2005a). In brief, a single extract was generated and then subdivided for the three different analyses (pesticides, PCB congeners, and PCDD/F congeners). The CLP Standard Operating Procedures (SOPs) were reviewed by USEPA and project team personnel prior to the initiation of the work.

<u>Total Suspended Solids</u>

A total of 380 environmental samples (*i.e.*, excluding those generated for quality assurance/quality control purposes) were analyzed for TSS by DESA. One anomalous data point has been determined to be not usable by the Quality Assurance Officer (QAO) and has been excluded from the calculations and interpretations. [TDB 051210-1330; the result was reported as not detected (4 U); the expected value would have been in the neighborhood of 40 or 60 milligrams per liter of water (mg/L).]

<u>Bromide/Chloride</u>

Bromide and chloride data were generated by DESA for 219 environmental samples. Based on the DESA narrative and subsequent reviews by the project team, the bromide/chloride data are considered fully usable.

Organic Carbon

Organic carbon analysis was performed by DESA on 231 samples (filters) prepared by USGS personnel. The RPD between duplicate and original samples were on average less than 25 percent; the average value is reported and used for calculations in this document. Low concentrations of POC [typically between about 0.01 and 0.02 milligrams (mg)] were detected in 8 of the 12 blanks associated with the filters. POC in the samples was, in almost all cases, at least five times greater than the highest blank concentration; as such, little effect on the sample data usability is expected. However, there is a possible high bias for low-level POC data.

A fewer number of filtered water samples (168 samples) were analyzed by DESA for TOC. This analysis, when performed on these filtered samples, represents DOC. The DOC concentrations were low and consistent (averaging about 4.1 mg/L, and ranging from 2.9 to 8.5 mg/L), as was expected. No organic carbon was detected in the blanks associated with the DOC analyses. These data are considered usable.

Metals

DESA analyzed and reported dissolved and total metals concentrations. DESA reported data for 19 metals, consisting of 18 of the CLP TAL metals plus molybdenum. The five metals, which were not reported by DESA are mercury (which was analyzed by a commercial laboratory, STL-OH), calcium, potassium, magnesium, and sodium. A total of 16 whole water samples (for total metals) and 10 filtered water samples (for dissolved metals) were analyzed. Subsequent to being reported by DESA, the data were further reviewed by comparison of the dissolved to total metals concentrations on paired samples, and assessment of field duplicates. The dissolved/total metals ratios were less than one (*i.e.*, dissolved-phase concentrations were less than the corresponding total metals concentrations), except for a few cases where the vanadium dissolved-phase concentration that was slightly higher (by less than 20 percent) than the corresponding total concentration. However, one of the two field duplicates for the total metals concentration did not agree well with an order of magnitude difference between the samples (resulting in RPD values greater than 100 percent). Review of the duplicate data suggests that this discrepancy may be a function of the duplicates not being identical; one of the samples may have had a higher suspended matter concentration than the other. This hypothesis is supported by two observations: first, the largest discrepancies were observed for metals that are primarily in the suspended matter (*e.g.*, aluminum and iron); and second, the agreement is acceptable (most RPD values are 25 percent or less) for the dissolved-phase sample duplicates.

Mercury

Low-level mercury analysis was performed by STL-OH on whole water samples (for total mercury) and filtered water samples (for dissolved mercury). To minimize the potential for introducing ambient contamination into the samples at the trace levels expected, all the samples for low-level mercury analysis were shipped (on ice but unpreserved) as whole water samples to the laboratory. The samples requiring filtration were filtered under clean, controlled conditions at the laboratory on the morning of receipt, and were then preserved at the laboratory. This approach is allowed by the method and was specified in the QAPP. Note that the laboratory-provided field blank was not submitted to the laboratory with the field samples; it was submitted later, which resulted in additional storage and container transfers. One field duplicate was analyzed, and the precision was less than 25 RPD.

Pesticides

As noted in Appendix J, individual pesticides could not be reported occasionally by the CLP laboratory due to matrix interferences. The pesticides data presented in this document (both for suspended and dissolved samples) were validated by USEPA personnel and, therefore, are considered fully usable. However, there are minor data gaps associated with individual pesticide compounds, which were not reported in some samples. The field blank did not yield detectable concentrations of target pesticides.

PCDD/F Congeners

The CLP laboratory analyzed the extracts for PCDD/F congeners as specified in the QAPP. The CLP laboratory also reported sums for the tetra- through octa- homolog groups for PCDD and also for the PCDF. Due to analytical difficulties, the laboratory was unable to report data for one sample (TU-GFF-051201-1130) despite multiple attempts. Many of the GFF samples were analyzed at a 5X dilution factor to reduce interference and keep target analytes within the calibration range. However, the reported 2,3,7,8-TCDD data are reported from undiluted (1X) analyses, except for TU-GFF-051208-1030, analyzed at a 5X dilution. These data were validated by USEPA personnel and are considered valid and usable, taking into account the qualifications as indicated in Appendix J.

PCB Congeners

The CLP laboratory analyzed the samples for PCB congeners using their SOP for implementation of USEPA Method 1668A. The laboratory was able to separate the 209 theoretical PCB congeners into 159 discrete peaks (which represent between one and five co-eluting congeners each). Homolog sums for monochlorobiphenyl through nonachlorobiphenyls were also reported by the laboratory.[21] In order to facilitate data manipulation for data users, the CLP laboratory reported a numerical value only for the lowest congener number of a co-eluting pair or suite (followed by a "C" in the data qualifier field); subsequent occurrences (of the remaining congeners in the co-eluting suite) were not reported with a value but contained a reference to the initial congener (*e.g.*, "C13") in the qualifier column.

The CLP laboratory had analytical problems with the monochlorobiphenyls in four of the XAD samples (GFF samples were not affected); as a result, there is no PCB-1 or PCB-2 data for four samples, and no PCB-3 data for one of those samples. As a result, the monochlorobiphenyl data are not complete. However, review of the data for other XAD

[21] The decachlorobiphenyl group consists of only a single congener, PCB-209. Consequently, no homolog sum was reported for that group.

samples where the CLP laboratory was able to report all three monochlorobiphenyls indicates that the overall contribution of the monochlorobiphenyls to the dissolved-phase PCB concentration is low. Monochlorobiphenyls comprise no more than about 2.5 percent of the total, but more typically about one percent (Appendix J).

Low levels of contamination for many congeners (up to about 60) were detected in laboratory blanks associated with both the XAD and GFF samples. The levels of blank contamination relative to the sample concentration were assessed by USEPA personnel performing the data validation. The default criterion was used in the assessment (*i.e.*, if the sample concentration is at least five times the blank concentration, the result is not qualified, and the "B" flag is removed; if the sample result is less than the associated blank, the reported concentration is negated; the B flag is removed and the result is flagged "U" at the lab-reported concentration or the reporting limit, whichever is greater). The PCB congener data presented and used in this document reflect this assessment; no B-flagged data have been retained.

In a few cases, individual PCB congeners did not meet the all the identification criteria specified in the method. Analogous to the practice for PCDD/F analysis, the CLP laboratory flagged these data "EMPC" (estimated maximum possible concentration). This flag was converted to "Q" during the USEPA data review (and the Q flag is used on the tables). Due to the uncertainty associated with the identification of the Q-flagged congeners, these individual congener results were not included as detected values in homolog sums or Total PCB calculations.

7.2.2 DISCRETE TSS MEASUREMENTS

Each TOPS boat had two ISCO automatic samplers that were utilized to collect samples for TSS, TOC, POC, and chloride/bromide analyses. Discrete TSS samples were collected at shallow and deep samples. During the pre-dredge monitoring program on December 1, 2005, the TSS measurements were recorded during daylight between 0800 hours EST and 1630 hours EST (Figure 7-14). Between 0800 hours EST and 1400 hours EST, ebb tide conditions were observed within the Pilot Study Area while flood conditions were observed during the remaining time. As expected, the TSS ranges for the upflow and downflow locations are similar since no dredging activities were occurring. The change in TSS concentration over time appears to be related to the movement of the salt wedge through the Pilot Study Area.

On December 5, 2005, the 13-foot MLW cut was constructed. All of the dredging activities were performed during ebb tide conditions that day, and for the most part, the upflow and downflow TSS ranges are similar (Figure 7-15). In contrast on the morning of December 6, 2005 (constructing the 11-foot MLW cut) soon after dredging started at 0930 hours EST, the TSS measurement (deep) downflow of the dredging operations was higher than the corresponding peak upflow TSS measurement. These observations potentially could be attributed to the dredging or the movement of the salt wedge (Figure 7-16). Later in the day, on December 6, 2005, during ebb tide, the upflow and downflow TSS ranges are similar. Shallow and deep TSS ranges both upflow and downflow of the dredging operation were also similar on December 7, 2005 (constructing the 15-foot MLW cut; Figure 7-17). However, TSS concentrations were much lower (less than 30 mg/L) than values reported during the pre-dredging concentrations.

Construction of the 15-foot MLW cut continued on December 8, 2005 during flood tide (Figure 7-18). Between 1030 hours EST and 1230 hours EST, the TSS ranges for the upflow and downflow locations are similar for the shallow samples but different for the deep samples. These observations could be attributed to the dredging or the movement of the salt wedge. Similar results were observed on the last day of dredging (December 10, 2005; Figure 7-19). Note that post-dredging monitoring occurred on December 12, 2005 (Figure 7-20); however, only one TOPS boat was used to collected data on this day. The TSS measurements recorded were lower than those recorded during the pre-dredge monitoring on December 1, 2005. The freshwater discharge on December 12, 2005 was much closer to the annual mean.

8.0 RESUSPENSION AND SUSPENDED SEDIMENT FLUX

The Pilot Study was designed to measure the amount of suspended sediment and associated contamination that was released by the dredging operation and subsequently transported downflow - away from the Pilot Study Area. This release is generically referred to as "resuspension" in the remainder of this document. The following section describes results from several analyses that were performed using the Pilot Study data to estimate dredge-related resuspension effects at the far-field (approximately 1,000 feet from the dredging operation), the near-field (approximately 400 feet from the dredging operation), and the very near-field (the area between the inner moorings and the dredging operation). Analyses and conclusions are specific to the Pilot Study, the dredging equipment employed, and the site examined.

Sediment resuspension (*e.g.*, the transport of solids only) was tracked as part of the hydrodynamic monitoring program, which was designed to collect redundant data from fixed points in space (moorings) and continuous ship-track surveys over larger spatial areas. Note that as discussed in Section 6.1.1, loss of data occurred at a few mooring locations due to either a malfunction of equipment at some time during the dredging program or due to physical damage, which occurred at Mooring 3 after a barge that was being repositioned contacted the mooring. However, loss of data did not irreparably impact the overall evaluation of resuspension during dredging because of the redundancy in the data collection program.

8.1 EXAMINATION OF SEDIMENT RESUSPENSION IN THE FAR-FIELD

Three evaluations were completed using the available far-field suspended sediments concentrations to estimate the magnitude of dredging-related suspended sediment transport in the far-field, which was defined as approximately 1,000 feet downflow from the Pilot Study Dredge Area (Figure 6-1). As discussed below, these evaluations were unable to distinguish sediment transport caused by the dredging operation relative to background conditions in the far-field during the Pilot Study.

8.1.1 EVALUATION OF DEPTH-AVERAGED TSS IN THE FAR-FIELD

Depth-averaged TSS concentrations were estimated from the data obtained by the ADCP sensors mounted on the far-field moorings (*i.e.*, Moorings 1 and 2 and Moorings 5 and 6). In brief, each ADCP signal (*i.e.*, ping) produces a vertical profile of sediment concentration from 80 centimeters above the sediment-water interface to approximately 60 centimeters below the water surface. The vertical resolution of the profiles is 25 centimeters at Mooring 1 through Mooring 5 and 50 centimeters at Mooring 6 (*i.e.*, the data are reported in 25-centimeter or 50-centimeter intervals through the water column for each mooring). At Mooring 2, data were recorded continuously at 1-second intervals and post-processed into 1-minute averages. For the other moorings, data were collected at 1-second intervals for 10 minutes every half hour. These data were processed by the ADCP sensors internally and reported once every half hour, yielding approximately 600 values for the study period for each sensor. The depth-averaged TSS for each mooring is then estimated as:

$$Depth\_Average\_TSS = \frac{1}{n}\sum TSS(z)$$

where n is the number of equally spaced depth intervals in the profile and $TSS(i)$ is the TSS concentration for the i^{th} depth interval. Refer to Appendix G for more detail on the calibration of the acoustic backscatter against suspended sediment measurements.

A comparison of depth-averaged TSS (as computed by the ADCP) by the four moorings on the outermost transects on either side of the dredging operation is shown on Figure 8-1. The upper panel in Figure 8-1 shows a comparison between the depth-averaged TSS at Mooring 1 (upriver deep channel) and Mooring 6 (downriver deep channel). The lower panel in Figure 8-1 shows a similar comparison between the depth-averaged TSS at Mooring 2 (upriver shallow centerline of the Pilot Study Dredge Area) and Mooring 5 (downriver shallow centerline of the Pilot Study Dredge Area).

Upon initial inspection, variations in the observed depth-averaged TSS (as computed by the surrogate measured by the ADCP) for each individual mooring are greater than any apparent difference between the upflow-downflow paired moorings in each panel. Moreover, the tidal variation in the depth-averaged TSS for both the upriver and downriver moorings frequently varied two orders of magnitude over one tidal cycle while yielding little apparent upflow to downflow difference. Consequently, a simple direct comparison of the depth-averaged TSS concentrations obtained at each mooring was unable to discern a dredging-related suspended sediment release above natural variable suspended sediment concentrations. This observation is in agreement with the preliminary modeling (Section 6.1.2; TAMS/ET, 2005) where the expected sediment load associated with dredging is typically much smaller than the signal due to natural background conditions (Figure 6-2) and the movement of the salt wedge. Notably, higher depth-averaged TSS values (greater than 100 mg/L) were recorded during the pre-dredging background monitoring period from December 2-4, 2005 than during the Pilot Study (December 5-10, 2005).

8.1.2 Evaluation of Far-Field Suspended Sediments During Peak Flow

Another method of evaluating the sediment resuspended by the dredging operation is to make a direct comparison between the sediment flux at the far-field moorings during maximum ebb and maximum flood conditions. This analysis represents a refinement of the evaluation presented in Section 8.1.1. During the maximum ebb and flood periods, water flows should be sufficiently consistent in direction and magnitude to permit the calculation of an interval mean. The mean values for the upflow and downflow moorings can then be compared to potentially identify dredging-related increases in suspended sediment transport.

For this analysis, a nominal 3-hour time interval was selected that corresponded with the higher velocities recorded by the ADCP instruments at Moorings 1 and 2 (upriver; Transect A) and Moorings 5 and 6 (downriver; Transect F) on December 3, 2005 and December 5-8, 2005. The results of this evaluation are presented in Figures 8-2 to 8-7. Each figure shows the suspended sediment flux and the water flow rates during maximum ebb or flood conditions. These figures allow for a direct comparison of flux with no time adjustment for the water parcel to travel from the upflow mooring to the downflow mooring. However, the averages suspended sediment flux compiled in Table 8-1 do account for this delay by allowing a one-half hour offset from the upflow to downflow transect. Supplemental information is also provided in Table 8-1, including average and maximum suspended sediment fluxes, average discharge as recorded by the ADCP, TSS measurements, and total volume of river water crossing Transects A and F in this nominal 3-hour time window. In general, this evaluation concluded that the changes in TSS measurements (or the suspended sediment fluxes) are within measurement error and that dredging-related suspended sediment transport could not be discerned at the far-field.

For Figures 8-2 through 8-7, it is important to note the precision of the water balance, since it factors directly in the suspended sediment flux calculation. Specifically, for each suspended sediment flux calculation obtained by each mooring, the measured TSS is multiplied by the water velocity at that location. Thus, the flux calculation is dependent on both the measured TSS and the water velocity measurements. By corollary, the suspended sediment flux is subject to any errors in the water flow measurements. In Figures 8-2 to 8-7 and Table 8-1, the calculated water flows expressed in units of cubic meters per second are shown for the upflow and downflow transects. Typical discrepancies in measuring water flows are on the order of 10 percent but may vary from -11 percent to +7 percent. These differences are attributed to measurement variability as well as the natural cross channel variability of estuary currents. They are not considered indicative of water loss or gain in the river since there are no significant sources of water to the Pilot Study Area and no means to store water in any fashion given the channel geometry. Based on the precision of the water balance, suspended sediment fluxes may vary on the order of 10 percent even if the absolute TSS concentration remained constant everywhere. Thus, differences in the suspended sediment flux of 10 percent or less are not considered significant. This conclusion is borne out by the calculations done for the baseline period (December 3, 2005; Figure 8-2 and Figure 8-3).

Comparisons were performed for the background monitoring period on December 3, 2005 during maximum ebb tide (Figure 8-2) and maximum flood tide (Figure 8-3). As the water flowed from upflow to downflow during the ebb tide, there was an apparent net average loss of 0.8 kilograms of solids per second (kg/s) in the calculated suspended sediment flux, representing a 2 percent decline in the flux relative to the upflow conditions. During maximum flood tide, there was an apparent net average loss of 1.3 kg/s in the calculated suspended sediment flux, representing a 16 percent decline. However, both of these periods are also characterized by a “loss” in the water flux of 8 percent and 11 percent, respectively. Correcting for these water losses would change the sediment fluxes substantively, resulting in a net increase of 6 percent for the ebb tide and much smaller net loss (5 percent) for the flood tide.

Suspended sediment fluxes (corrected and uncorrected for flow differences) are considered to represent the minimum range of baseline suspended sediment transport uncertainty that must be exceeded to identify a dredging-related release at the far-field because of the differences in the timing of the flow and suspended sediment balances[22] as well as the possible additions or losses of suspended sediments from the Pilot Study Area apart from the dredging operation. As discussed below, few of the calculated differences exceeded this threshold, and in fact, one of the periods exhibited a loss so great that it is likely that this baseline variability is underestimated. The observations for each of the individual averaging intervals include:

- <u>December 5, 2005 (maximum ebb conditions, Figure 8-4)</u>: Upriver (or upflow) of the dredging, the average suspended sediment flux was 13 kg/s while downriver (or downflow) of the dredging, the average sediments flux was 14 kg/s, yielding a net average gain of 1 kg/s. This increase in solids represented an increase of 11 percent relative to the upflow conditions without a flow correction (or 7 percent with a flow

[22] Water flow begins to respond to tidal forcing more rapidly than the longitudinal movement of suspended sediments from upflow to downflow locations.

correction), and therefore, is not considered to exceed the range of measurement error.

- December 6, 2005 (maximum ebb conditions, Figure 8-5): Upriver (or upflow) of the dredging, the average suspended sediment flux was 12 kg/s, and the average suspended sediment flux downriver (or downflow) was 13 kg/s, a net average gain of 1 kg/s. This difference represents a net increase of 12 percent uncorrected for flow. During this period, there was an apparent large water loss (-10 percent), which would raise the relative suspended sediment flux increase to approximately 22 percent of the upflow flux. This gain would appear to be outside the range of variability expected from baseline conditions. However, based on later observations during the Pilot Study (refer to December 8, 2005 discussion below) where similar scale decreases occurred, this loss is not considered to exceed the range of the measurement error.
- December 7, 2005 (maximum ebb conditions, Figure 8-6): The average suspended sediment flux both upriver and downriver of the dredging operation was 2.2 kg/s, representing a relative change of zero percent. The flow correction did not substantively change this flux, yielding only a 1 percent increase in the suspended sediment flux, which is considered within the measurement error.
- December 8, 2005 (maximum flood conditions, Figure 8-7): The average suspended sediment flux upriver (or downflow) was 6.4 kg/s, and the average downriver (or upflow) sediment flux was 7.4 kg/s. As the water flowed from downriver to upriver during this time period, there was an apparent net average loss of 1.0 kg/s in the calculated suspended sediment flux, a decrease of 13 percent relative to the upflow condition. Correcting for the apparent water "gain" yields a suspended sediment flux decrease of -20 percent. The magnitude of the suspended sediment flux decrease is large and would appear to be beyond the baseline condition. However, it is unlikely that activities associated with the dredging operation would result in such a loss of sediments from the water column. Instead, this decline is attributed to a combination of natural variability and measurement uncertainty.

Based on the observations for suspended sediment flux and water flow at the far-field transects, it is apparent that the natural flux of sediment carried by the river was greater than any suspended sediment flux resulting from the dredging operations. Thus, the use of the far-field moorings to estimate the dredging-related suspended sediment flux became an exercise in the difference of large numbers. For the intervals examined on December 5, 2005 and December 7, 2005, the differences observed between upflow and downflow mooring transects was well within the range of conditions observed during baseline monitoring (December 3, 2005). For the remaining two intervals examined, one exhibited a sediment increase (December 6, 2005) that appeared on face value to exceed the baseline uncertainty. However, the other interval (December 8, 2005) exhibited a loss of comparable magnitude, implying that baseline variability had been underestimated by the baseline monitoring. Consequently, this comparison of the suspended sediment flux at the far-field moorings during maximum ebb and maximum flood flow conditions yields no detectable increase in the suspended sediment flux by the dredging operation.

8.1.3 Evaluations of Suspended Sediment Flux Based on Measured TSS in the Far-Field

The last analysis of the far-field suspended sediment flux was conducted using the TSS measurements collected by the monitoring vessels (as opposed to the moorings). A pair-wise analysis was conducted using paired TSS data obtained from the ISCO samples used to collect water column samples for chemical analysis. Pairs of matched TSS samples were used to evaluate net suspended sediment flux across the two far-field mooring transects (the boat-based sampling at Moorings 1 and 2, Transect A and the boat-based sampling at Moorings 5 and 6, Transect F).

For this analysis, the time of transit across the Study Area (or delay time) was required to identify pairs of TSS samples that represented approximately the same parcel of water on each side of the dredging operation. The delay time was calculated by dividing the distance between Moorings 1 and 6 by the depth-average velocity obtained at the two moorings. The delay time was then plotted against date and time (Figure 8-8). On average, the delay time during ebb tide is approximately 15 minutes and during flood tide the delay time is approximately 20 to 30 minutes. However, a delay time of 30 minutes was selected for the TSS paired data since the TSS samples were collected every 30 minutes and the sample collection occurred about every 15 minutes. In this manner, the upflow TSS sample was matched to the downflow sample collected 30 minutes later. The matched pairs were identified only for periods when the delay time was less than 60 minutes; periods with a delay time or more than 60 minutes corresponded to water parcels that were unlikely to travel directly from one transect to the other.

The gross suspended sediment flux at each end of the Study Area was then calculated by multiplying the TSS concentration by a mean cross-sectional area[23] and the depth-averaged velocity for Transect A (Moorings 1 and 2). A single estimate of flow for each pair (*i.e.*, cross-sectional area multiplied by the depth-averaged velocity) was used in the suspended sediment flux calculation because the sampling process integrated much of the river cross-sectional area in each transect and no additional information on flow was available to permit a more complex integration. Once the gross suspended sediment flux was obtained for each TSS sample in a matched pair, the net suspended sediment flux was obtained by the simple difference.

The net suspended sediment flux was calculated during both active dredging time periods and non-dredging time periods (Table 8-2). The average and median net suspended sediment flux during dredging period are approximately 3 kg/s and 1 kg/s, respectively. For comparison, the average and median net suspended sediment flux during non-dredging period are approximately 2 kg/s and 0.3 kg/s, respectively. At first glance, these results would suggest a difference between dredging and non-dredging periods. However, the uncertainty on each of the mean values is quite large as is illustrated by the magnitude of the standard error on the mean (provided in Table 8-2). Thus, the net mean suspended sediments flux for dredging periods becomes 2.9 ±1.9 kg/s and for non-dredging periods, the net mean suspended sediment flux is 2.0 ±2.4 kg/s. On this basis

[23] The cross-sectional area was calculated based on the 2004 bathymetry survey elevation relative to NGVD29. The MLW elevation for the cross-sectional area is approximately -2.3 feet below the zero NGVD29 elevation. Mooring elevation data accounted for the tidal variations in river surface elevation during dredging and its effect on the cross-sectional area.

alone, the results indicate the lack of a measureable dredging-related suspended sediment flux (Figure 8-9). However, to confirm this conclusion, a more rigorous set of statistical analyses were conducted. Based on the Tukey-Kramer test of significant difference and the Wilcoxon/Kruskal-Wallis non-parametric rank sums tests,[24] the net suspended sediment fluxes during both dredging and non-dredging periods are not statistically different. Therefore, like the prior analyses in this section, the estimates of suspended sediment flux by direct measurement of water column suspended solids did not reveal a net suspended sediment flux in the far-field due to the dredging operations.

8.2 EXAMINATION OF RESUSPENSION SEDIMENT IN THE NEAR-FIELD

In addition to examining the far-field data, the dredging-related suspended sediment flux in the near-field was evaluated (approximately 400 feet from the Pilot Study Dredge Area; Figure 6-1). This examination included the particle size distribution data obtained by the monitoring vessel (*R/V Julia Miller*) and the suspended sediment data collected at the near-field moorings (Moorings 3 and 4). A principal component analysis was conducted on LISST particle size distribution data to determine if particle size distribution differed between upriver and downriver conditions during dredging in the near-field. This evaluation concluded that variation in the suspended sediments distribution is unrelated to dredging operations or tidal cycle.

The objective of principal component analysis is to reduce the dimensionality of a dataset that contains a large number of inter-related variables (over 16,000 records containing 32 bins of particle sizes were recorded). This reduction is achieved by transforming the data to a new set of uncorrelated reference variables (*i.e.*, principal components). The principal components are reported such that each component in turn accounts for a progressively smaller percentage of the total variance within the dataset. Because each LISST data set contains 32 bins of grain size information, reducing the information to a small subset of principal components provides a simplified method to understand any

[24] The Wilcoxon/Kruckal-Wallis test showed the Chi-Square value was 0.5387 and a probability greater than Chi-Square of 0.463, which indicates that the means are not statistically different.

differences in the particle distribution due to dredging. Ideally, the particle size distribution in the dredge plume downflow of the operation would appear different from the particle size distribution upflow. The key steps in the principal component analysis include: data transformations, eigenvector decomposition, determination of the number of significant eigenvectors, and visual display of principal component results. Each of these steps is discussed below.

- Data Transformation: Principal components are in general not invariant with respect to changes in scale. Thus, data measured on different scales or on a common scale with widely differing ranges are often transformed. In this analysis, a constant row-sum transformation was used where each value is divided by the total concentration of suspended sediments in the sample. In this fashion, the analysis focuses on the percent changes in individual parameters and not their absolute magnitude. For example, a percent change in the particle distribution is of equal importance whether it occurs in a sample with high suspended solids or low suspended solids.
- Eigenvector Decomposition: Eigenvector decomposition allows for the reduction in dimensionality of the data set through singular value decomposition. The software JMP (Statistical Discovery™ from SAS, Release 6.0.0) was used for the principal component analysis. The results of the analysis present about 32 eigenvectors, or 32 principal components. The eigenvalues are depicted from the largest to the smallest in Figure 8-10 for the LISST data collected on the *R/V Julia Miller* and Figure 8-11 for the LISST data collected on the moorings.
- Number of Significant Eigenvectors: After determining how much variance each successive principal component extracts, the next step is to determine the number of significant components to retain. While there are numerous methods used to make this determination, the screen test (Cattell, 1966) is used in this analysis. This method is based on the premise that the variance levels off at the point where the principal components begin to account for random error. The point where the curve begins to level off should show a noticeable inflection point or "elbow." On Figure 8-10 (LISST data collected on the *R/V Julia Miller*) and Figure 8-11 (LISST data collected on the moorings), an elbow occurs between the second and third principal

components. Consequently, two or three components effectively summarize the total sample variability in each dataset.

A "score plot" on a two-dimensional or three-dimensional graphic is the most common way to present principal component analysis. This presentation allows the evaluation of relationships between sampling conditions upriver and downriver of the dredge operations. Scores plots for the *R/V Julia Miller* LISST data are presented in Figures 8-12 and 8-13. Interestingly, the three principal components do not separate the *R/V Julia Miller* LISST data upriver and downriver of the dredge. Furthermore, there is no differentiation of the *R/V Julia Miller* LISST data based on the tide stage. This observation indicates that the variation in the particle size distribution is unrelated to the dredging operation or flow direction in the tidal cycles in the near-field. While further evaluation may discern the cause of the variability in the data, it is apparent that the pattern changes are unrelated to dredging-related processes or conditions. This conclusion is not surprising given the non-measurable impact of dredging on suspended sediment fluxes in the far-field as described earlier in this section.

Similar plots were constructed with the mooring data (Figures 8-14 and 8-15). In general, the data from the moorings yielded similar results, that is, the data do not consistently separate on tidal direction, which would suggest a dredging-related change in particle size distribution. However, in Figure 8-14, a cluster of points occurs in the top left corner of the plot, corresponding to ebb tide at Mooring 3. Review of the data suggest that Mooring 3 generally reported lower suspended sediment concentrations, and about half of the results from Mooring 3 during ebb tide are included in this cluster. In Figure 8-15, the data create two clusters, one for each mooring regardless of tidal direction. The lack of response to tidal direction at either mooring indicates that dredging-related impacts were not discerned by the changes in particle size distribution. The observation that particle size data collected at Moorings 3 and 4 were separated by the principal component analysis while the particle size data collected by the *R/V Julia Miller* were not, suggests that there may be some differences in the instrument calibration at the moorings or that location-based differences suggested by the fixed mooring data were simply not discernable in the more randomly placed *R/V Julia Miller* surveying locations.

Like the observation of suspended sediment flux, observations with the particle size data suggest that the local resuspension in the river provides the vast majority of suspended sediment in the water column, making it difficult to accurately quantify the impact of sediments resuspended by dredging. Ultimately, the data suggest that the particle size distribution in the water column at the time of the Pilot Study was insensitive to the dredging-related resuspension. This insensitivity may be related to several issues including the possible similarity of the particle size distribution for both naturally and dredging-related resuspension but is more likely due to the relatively small increase in the net suspended sediment flux due to dredging.

8.3 EXAMINATION OF RESUSPENSION SEDIMENTS IN THE VERY NEAR-FIELD

Two evaluations were completed to evaluate dredge-related resuspension effects in the very near-field, which is defined as the region between the inner moorings (Moorings 3 and 4) and the Pilot Study Dredging Area. In most instances, these evaluations focused in the region approximately 60 to 300 feet from the dredge operation. These evaluations included a harmonic analysis on mean flow and tidal current velocity data as well as an integration of two-dimensional estimated TSS. The results of these evaluations indicate that dredge-related resuspension is detectable in the very near-field, despite a wide variation in the background suspended sediment load. However, this signal is apparently rapidly dissipated since it is not readily discernable in the near-field (approximately 400 feet from the dredging operation; refer to Section 8.2).

8.3.1 HARMONIC ANALYSIS OF MEAN FLOW AND TIDAL CURRENT VELOCITY

Using the shipboard data from the *R/V Caleta*, estimates of the cross channel structure of the tidal and tidally averaged flow have been made by performing a harmonic analysis of the ADCP data. This estimation was conducted by defining 20-meter grids along two river cross-sections (one upriver and one downriver from the dredging area) and generating a time series of velocity measurements within each grid. From December 5-10, 2005, each grid was visited approximately 50 to 100 times, thus providing essentially fixed point velocity measurements with a resolution of 20-meters in the horizontal plane and 25-centimeters in the vertical direction. Each time series was fit using least squares regression to a mean flow plus a tidally fluctuating component:

$$u(x,z,t)=u_o(x,z) + U(x,z) * \sin(\omega t + \Theta_u)$$
$$v(x,z,t)=v_o(x,z) + V(x,z) * \sin(\omega t + \Theta_v)$$

where u and v are the east/west and north/south flows which are decomposed into their respective tidal mean currents, u_o and v_o, and the tidally oscillating flow with amplitudes U and V and phases Θ_u and Θ_v. The spatial dimension is defined as x in the cross channel direction, y along the channel, and z in the vertical; t is time; and ω is the frequency of the major semidiurnal tide with a period of 12.42 hours.

Figure 8-16 shows a map of the cross-section locations in the Pilot Study Area as well as the results of this harmonic analysis. The light blue boxes on the map show the location of the grids used to generate the fixed-point time series from the ADCP data. The two panels on the left correspond to a cross-section that is upriver from the dredging area and the two panels on the right column correspond to a cross-section that is downriver from the dredging area. The top panel in each column shows the along-channel mean flow. The bottom panel in each column shows the amplitude of the along-channel tidal current velocity. These results were determined based on a principal component analysis of the results of the least-squares fit. Ship tracks from the *R/V Caleta* for all five days of dredging were used to generate these graphics.

The top panel on the left shows a mean surface outflow upriver of the dredge area of 20 to 30 centimeters per second (cm/s) that is concentrated in the northern half of the channel and near zero mean flows near the bed that are offset toward the southern side of the channel. This residual flow structure (or tidally averaged flow) is consistent with theoretical concepts of the interaction between tidal and residual flows downriver of a bend in the channel (Geyer, 1993 and Chant, 2002). In the absence of a channel bend, the upper layer is expected to flow seaward with a weak return flow at depth. However, inertia associated with the channel bend upriver from this section drives the upper layer outflow to the north side of the channel with a compensatory lower layer flow to the south.

The amplitude of the tidal current (shown in the bottom left panel) along this cross-section exhibits a similar structure with enhanced tidal current speeds of over 50 cm/s located at the surface on the north side of the channel with reduced velocities at the bottom on the southern side. Note that these tidal currents are superimposed on the mean flow. Thus, during maximum ebb tide they are additive and the surface layer ebbs at 75 cm/s (1.5 knots), while during the flood tide they are opposed and surface flows peak at only 25 cm/s (0.5 knots). Consequently, processes that are non-linear, such as flow curvature that involves centrifugal accelerations and are proportional to the square of the velocity will be more pronounced during the ebb tide. In the absence of flow curvature, the expected structure of the tidally varying flow would be enhanced tidal currents at the surface near the center of the channel and weaker tidal currents at depth. However, secondary flows associated with the channel bend drives the surface velocities to the north (outside of the bend) and the lower layer velocities to the south (inside of the bend).

In contrast, the cross-channel structure of the flow immediately downriver from the dredge area (right panels) shows a completely different picture. Both the tidal mean flow and the tidally varying flow have maximum currents at the surface on both the north and the south side of the channel with a local minimum in between what appears to be centered on the location of the dredging operation. This flow structure suggests that rather than being associated with natural estuarine processes, it is due to the interaction between the flow field and the dredging operation. The perturbation of the flow is significant and results in a factor of two reduction in surface current during peak ebb and a significant change in its vertical structure. This perturbation could have a profound impact on the transport of sediments resuspended by the dredge and is likely, due to reduced velocities, to limit the dispersion of sediments away from the dredging operation.

The disturbance of the flow field by the configuration of the dredging operation represents a possible reduction in local velocities during the Pilot Study, potentially reducing sediment transport away from the dredge. In terms of the representativeness of the Pilot Study, this flow reduction by the equipment is at least partially offset by the higher than average flow conditions that occurred during the dredging operations. As noted in Section 7.1.1, freshwater discharge ranged from 1,800 ft^3/s to 3,100 ft^3/s during the Pilot Study. This range of freshwater discharge is higher than the mean December freshwater discharge of 1,300 ft^3/s and the annual freshwater discharge of 1,100 ft^3/s as reported at the USGS gauging station at Little Falls, New Jersey. However, this freshwater discharge range is not uncommon for the Lower Passaic River since there is approximately a 1-in-4 chance of freshwater discharge exceeding 1,800 ft^3/s in December (which corresponds to flows observed on December 5-7, 2005 during the Pilot Study).

8.3.2 Integration of Two-Dimensional Estimated TSS in the Very Near-Field

The *R/V Caleta* shipboard surveys from December 5-8, 2005 and December 10, 2005 provide two-dimensional estimates of TSS (as computed by the surrogate measured by the ADCP) along several cross-sectional transects. Sediment resuspension during mechanical dredging is not a continuous process but occurs as a series of discrete or intermittent short-lived pulses during each dredge cycle. A typical example of this intermittent resuspension during dredging is depicted in Figure 8-17, which presents estimated TSS concentrations at a fixed transect downflow of the dredge on December 8, 2005 between 1138 hours EST to 1141 hours EST. This figure shows that elevated TSS concentrations indicative of a plume were estimated in the upper water column between the horizontal positions of 30 to 70 meters at 1139 hours EST. By 1141 hours EST, significant decreases in the TSS concentrations occurred at the same transect location, indicating that the pulse was short-lived. These short-lived resuspension pulses can only be created during the portion of the cycle time when the dredge bucket is in the water column or over the water. Consequently, multiple passes of the shipboard vessel were needed to completely characterize the average net suspended sediment flux that was representative of the conditions during the dredging period.

The objective of integrating the two-dimensional estimates of TSS from the shipboard surveys was to determine the net suspended sediment flux in the near-field area during dredging. Several approaches were used to estimate the near-field resuspension input utilizing the ADCP cross-sections by comparing upflow cross-sections with downflow cross-sections (including a plume-width basis method and a cross-section basis method). Because the upflow condition varied significantly, the baseline load had to be estimated for each downflow cross-section examined. A summary of the approaches identified below are described in more detail in the referenced appendices.

- Plume-Width Basis Method: Net suspended sediment flux was estimated based on the difference in simple matched cross-sections without further correction for difference in cross-section length. Following this method, 27 matching cross-section pairs were evaluated by Rutgers University and presented in Appendix G. In this evaluation, a plume was evident for only 8 of the 27 matched cross-section pairs, and net suspended sediment fluxes were estimated for these 8 matched pairs.
- Plume-Width Basis Method Modified: In the work presented in Appendix G, when a plume was identified, it was generally observed between the horizontal positions of 30 to 70 meters. The Louis Berger Group, Inc. then estimated the net suspended sediment flux by determining a matching upflow load and by normalizing for flow within the width of the plume. This calculation was repeated for the 19 matched cross-section pairs originally presented in Appendix G, in which Rutgers University did not identify a dredge related plume, plus three additional pairs identified by The Louis Berger Group, Inc. (a total of 22 matched pairs; details are presented in Appendix L). The net suspended sediment flux calculated by The Louis Berger Group, Inc. for the 22 matched pairs plus the 8 matched pairs identified by Rutgers University are listed in Table 8-3.

- Cross-section Basis Method (Part 1): Net suspended sediment fluxes were estimated from the full downflow ADCP cross-sections measured by the *R/V Caleta* and determining a matching upflow load by normalizing for flow. This analysis was conducted based on time-of-travel determination in matching the upflow and downflow cross-sections (refer to Appendix M).
- Cross-section Basis Method (Part 2): Net suspended sediment fluxes were estimated based on extrapolation of downflow ADCP cross- sections to the entire river cross-section and determining a matching upflow load by normalizing for flow. Like the methods described above, time-of-travel was used to match the upflow and downflow cross-sections (refer to Appendix M).

Dredging-related resuspension was estimated using the plume-width basis method and the cross-section basis method. These two methods yield the most consistent results because:

- They focused on the plume-bearing portion of the cross-section.
- They were normalized to flow.
- They did not extrapolate the downflow cross-section.

The plume-width basis method was used to estimate 30 net suspended sediment fluxes while the cross-section basis method was used to estimate 18 net suspended sediment fluxes (Table 8-3; Appendix L). These estimated net suspended sediment fluxes were then compared using a probability plot (Figure 8-18). With the exception of the results that are plotted on the extreme ends of the probability plot, the net suspended sediment fluxes from the two methods (plume-width basis and cross-section basis) are fairly similar with comparable medians. However, the distribution of the net suspended sediment flux calculated from the plume-width method is more right-skewed given its concave shaped probability plot. A test of the results generated from the two methods clearly showed no statistical difference between the two groups, with a mean value for the plume-width basis method of 0.79 ±0.37 kg/s and a mean for the cross-section basis method of 0.72 ±0.52 kg/s (where the error bar represents two standard errors). Because of the similarity in the means and distributions of the suspended solids fluxes by the two methods, the results were combined for further analysis.

Both approaches showed net suspended sediment fluxes in the very near-field that varied over time with net suspended sediment fluxes on December 7, 2005 and December 8, 2005 lower than those values observed on the other dredging days (Figure 8-19). These data are re-grouped on a "range bar plot" in Figure 8-20 to show the estimated daily mean and median net suspended sediment flux for each day. The mean and median net suspended sediment fluxes for each day were generally quite similar for the first three days of the Pilot Study (December 5 through 7, 2005). A statistical test of means (Tukey-Kramer Honestly Significant Difference) comparing the suspended solids flux showed that the mean fluxes for December 7, 2005 and December 8, 2005 were significantly lower than those fluxes observed on December 5, 2005 and December 6, 2005. Based on the calculations summarized in Table 8-4, the average net suspended sediment flux at the very-near field on December 7, 2005 and December 8, 2005 were more than three times lower than the flux calculated on December 5, 2005 and December 6, 2005. The suspended sediment flux calculated on December 10, 2005 by comparison had so much variability that it could not be statistically discerned from either of the other two-day periods.

8.3.3 Impacts of Dredging Operations on Resuspension in the Very-Near Field

The relationship between the dredging operation and dredge-related resuspension in the very near-field was then investigated. The estimated daily net suspended sediment flux was observed to vary inversely with the dredging cycle time, with longer cycle times associated with less daily net suspended sediment flux (Figure 8-21). Notably, the change in total cycle time (about a 50 percent increase from the low value to the highest value) is not commensurate with the change in magnitude of the net suspended sediment flux (from approximately 0.3 kg/s to 1.6 kg/s). Further examination of the relationship between dredging production rate and the total cycle time shows that the two parameters were correlated but not directly proportional (Figure 8-22 and Table 8-4), as might be expected, suggesting that other factors, such as number of lifts per area, impacted the dredging production and dredging-related suspended sediment releases.

While the results may have limited applicability as true estimates of the long-term net suspended sediment flux, the suspended sediment flux estimated for each day can be normalized to the productivity for each day by dividing the net suspended sediment flux by the productivity rate (both expressed in kg/s) to determine the very near-field percent resuspension (Table 8-4).[25] Relatively lower percent resuspension (2.3 percent) was observed in the very near-field on December 7, 2005 and December 8, 2005 when Best Management Practices and operational controls were optimized. This optimization resulted in longer cycle times and less volume removed per dredge, which consequently led to a lower maximum operating production rate (130 cubic yards/hour). A storm event on December 9, 2005 is likely responsible for the large suspended sediment flux variations (4.3 percent) observed on December 10, 2005 even though Best Management Practices were in place. The variability in the suspended sediment flux estimates for that day is likely evidence of the storm's impact. Conversely, relatively higher percent resuspension (5.5 to 5.7 percent) was observed in the very near-field during the first two days of the Pilot Study when dredging techniques were being tested and maximum operating production rates were higher (200 cubic yards/hour).

While this analysis did provide an estimate of the dredging-related suspended sediment flux in the very near-field, it is considered an upper bound on the amount of suspended sediment that might escape to the far-field since flocculation and settling are expected to substantively reduce this flux downflow. Moreover, this signal is not discernable from background in the near-field, indicating that dredge-related solids settle out of the water column or are dispersed between the very near-field and the near-field. Some of these

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[25] Unit conversion uses a dry bulk density value of 553 kg/m^3 derived from wet bulk density measurements and percent solids reported during the July 2004 sediment coring program (TAMS/ET and Malcolm Pirnie, Inc. 2005b).

solids may subsequently combine with the regularly suspended sediments layer and may be transported with the tidal currents. As noted in Section 8.1, detection of dredge-related resuspension at the far-field could not be discerned above baseline suspended sediment transport, indicative of the relatively small increase in the suspended sediments caused by the dredging operation relative to the natural solids load normally carried by the river. To some extent, some of the decreased sensitivity at the far-field would also result from settling that occurs between the dredge and the far-field observation points.

8.4 SEDIMENT PROFILE IMAGING AND RESUSPENSION

SPI technology was used during the Pilot Study to image the sediments and document the occurrence of an oxygenated layer, as identified by a redox potential discontinuity depth. If this layer could be attributed to dredging-related disturbances, then the SPI image could be used to document the thickness of a dredging residuals layer. To establish the thickness of the dredging residuals, the Pilot Study took advantage of a SPI survey conducted prior to the dredging pilot in the Lower Passaic River, which was used to estimate the thickness of the oxic layer under baseline conditions.

The SPI results indicated an average redox potential discontinuity depth of 1.7 centimeters for stations located upriver and downriver of the Pilot Study Area in June 2005 (pre-dredging conditions). In contrast, the redox potential discontinuity depths in sediments located both inside and outside the Pilot Study Area in December 2005 were approximately 6 centimeters (Table 4-2). One explanation for this difference in redox potential discontinuity depth could be difference in total organic carbon. Variable total organic carbon contents can contribute to variable dissolved-oxygen levels in the sediments, which in turn can impact the redox potential discontinuity depth. However, the total organic carbon content in the surface sediment (0-1 foot) in the Pilot Study Area was rather constant [average 5.6 ±0.57 percent; *Final Data Summary and Evaluation Report* (TAMS/ET and Malcolm Pirnie, Inc., 2005b)]. Instead, given that the baseline suspended sediment transport dwarfed any dredging-related sediment resuspension, it is clear that the change in the redox potential discontinuity depth outside the dredging zone cannot be attributed to the Pilot Study.

Redox potential discontinuity depths that are greater than a depth of 1 centimeter can result from bioturbation by infauna (Rhoads, 1974 as cited in Appendix E) or major resuspension/deposition events that oxygenate the sediments (Don Rhoads, personal communication as cited in Appendix E). The benthic invertebrate community survey (Aqua Survey, Inc., 2005) indicated that the bioturbating infauna population was relatively low on the Lower Passaic River, so this factor alone is an unlikely explanation for the increase in the redox potential discontinuity depth from June 2005 to December 2005. For the benthic organisms that are present in the river, their activities will be reduced in December because of the colder water temperatures, which in turn will increase oxygen solubility, which in turn could increase the redox potential discontinuity depths. However, reduced oxygen demand is unlikely to yield the redox potential discontinuity depths of 7 to 18 centimeters that were observed outside the dredging zone. Consequently, a major resuspension/deposition event is likely responsible for the marked increase in average redox potential discontinuity depth observed between June 2005 (1.7 centimeters) and December 2005 (6 centimeters) as well as the location-to-location variability outside the dredge zone since sediment types in this area of the river are relatively consistent.

A series of storm events in the six-month period prior to the December 2005 SPI survey was recorded at the USGS gauging station located at Little Falls, New Jersey (located 12 miles upriver of the Dundee Dam). There were two large storm events reported in October 2005, and one storm event occurred just three days prior to the commencement of dredging (and just 11 days prior to the SPI survey). River flow was nearly five times greater in December 2005 during the dredging activities (1,900 ft^3/s) than in June 2005 during the benthic community survey (220 ft^3/s; Figure 8-23). There was also a storm event on December 9, 2005 during the Pilot Study. This storm event can be readily observed on the water surface elevation data measured at Mooring 2 (Figure 7-3).

While it is likely that storm activity between June and December yielded the increase in the redox potential discontinuity depth, it is also useful to rule out the dredging activities associated with the Pilot Study. Based on the observed suspended sediment flux alone, the dredging operation yielded less than 10 percent of the water column borne suspended sediment during the Pilot Study. Given that dredging activities occurred over only a small time interval between June 2005 and December 2005, it is unlikely that this small addition to the suspended sediment transport could have yielded the increase in the observed redox potential discontinuity depth. Moreover, if 1 percent of the dredged solids were redeposited over the Pilot Study Dredging Area and assuming a re-deposition density of 0.25 grams/cubic centimeters, the residuals would form a layer of only about 2 centimeters thick. Therefore, re-deposition of resuspended sediments alone could not have been the cause of the increased redox potential discontinuity depth since, in reality, the resuspended sediments would have settled over a much larger area. These considerations rule out the Pilot Study as the source of the change in the redox potential discontinuity depth outside the dredging area.

Moreover, while the average redox potential discontinuity depths inside and outside the Pilot Study Dredging Area are essentially the same, the corresponding variances are not. The redox potential discontinuity depths show a statistically smaller variance for locations inside the Pilot Study Dredging Area than those locations outside the dredging area. Given the closeness in time between the completion of the Pilot Study and the December 2005 SPI survey, the redox potential discontinuity depths within the dredging area represent a residual layer thickness on the order of 6 centimeters or less (approximately 2 inches), allowing for some additional reworking and deposition in the brief intervening period. It is unlikely that the redox potential discontinuity depths observed in the Pilot Study Dredging Area are due to the same processes that created the oxic layer outside the dredging area. The observation of a residual layer of this thickness is consistent with other observations reported in the literature (USACE, 2008b).

8.5 WATER QUALITY MONITORING PROGRAM

The main goal of the water quality monitoring program was to measure the increase in contaminant transport downflow of the dredging operation that resulted from sediment resuspension. A second objective of this program was to investigate and confirm that most of the contaminant transport is via the suspended-phase as opposed to the dissolved-phase. In brief, the contaminant concentrations on suspended sediment and in the dissolved-phase were compared with the background chemistry, the bottom sediment chemistry, and other known concentrations in the Lower Passaic River from samples collected by the Stevens Institute of Technology during the New Jersey Contaminant Assessment and Reduction Project (CARP) conducted by NJDEP in 2000-2002. Refer to Appendix H for further discussion on data collected on the water quality monitoring program.

Table 8-5 presents the data collected by the TOPS vessels from the upriver and downriver sample-pairs reported for dissolved-phase and suspended sediment on a volume basis. These results show that the suspended sediments are transporting the majority of contaminant mass, typically 90 percent or more. Moreover, the results also show the lack of consistent contaminant concentration gains across the Pilot Study Dredging Area. Table 8-6 shows the converted concentrations of selected organic analytes in suspended sediment samples collected by the TOPS vessels from December 1-12, 2005. Refer to Appendix H for further discussion on dissolved-phase concentrations. The organic analytes selected for the evaluation of the suspended-phase fate and transport were: 2,3,7,8-TCDD, Total DDT, and Total PCB. The metals selected for this analysis were lead and mercury.[26] For comparison, Table 8-7 presents the average concentrations of 2,3,7,8-TCDD, Total DDT, and Total PCB that were detected in the upper three feet of sediment in the 15 cells of the Pilot Study Dredge Area collected in July 2004.

In general, the contaminant concentrations in the suspended sediment both upflow and downflow of the dredging operation were similar to the corresponding concentrations in the surface sediments, indicating that baseline resuspension was the primary source of the

[26] These analytes (2,3,7,8-TCDD, Total DDT, Total PCB, lead, and mercury) were evaluated in the *Final Data Summary and Evaluation Report* (TAMS/ET and Malcolm Pirnie, Inc., 2005a) and were selected for the Pilot Study because they had high concentrations in the sediment. Total PAH was not selected as an organic analyte because concentrations were relatively low and would not produce an acceptable signal to noise ratio relative to the PCB and PCDD/F congeners.

suspended sediments contamination. This observation also indicated that dredging-related resuspension did not affect concentrations on downflow suspended sediment. These results are consistent with the observations of suspended sediment transport; that is, dredging-related resuspension of sediment could not be measured and therefore was small in comparison to baseline suspended sediment transport during the Pilot Study. The majority of contaminant mass was consistently found on the suspended sediment, which indicates that the contaminant transport is primarily in the suspended-phase. Paired samples collected upflow and downflow of the dredging operation were also compared, but concentration changes were within the range of the analytical measurements and illustrate the heterogeneous nature of contamination in the Lower Passaic River. A brief overview of the water quality monitoring program is described below. Appendix H contains a full discussion of the data (including suspended-phase and dissolved-phase) collected during the water quality program.

- On December 1, 2005, when no dredging activities were occurring, contaminant concentrations were observed as the water moved past the Pilot Study Area. In the suspended-phase, there appears to be an increase of 40 percent in the Total DDT concentration per unit volume, accompanied by a decrease in the Total PCB (approximately 16 percent), lead (approximately 19 percent), and mercury (approximately 14 percent) as the water moves past the Pilot Study Area from upriver to downriver. The concentration of Total DDT, Total PCB, 2,3,7,8-TCDD, lead, and mercury on the suspended sediments were similar to the corresponding surface sediments, suggesting that the contaminant transport is primarily in the suspended-phase. Moreover, these data highlight the natural variation in the suspended contaminant concentrations.
- On December 5, 2005, the integrated samples were collected during an ebb tide as dredging was being performed in the 13-foot MLW cut. In the suspended-phase, there appears to be a decrease in the 2,3,7,8-TCDD and Total DDT concentrations and an increase in the Total PCB, lead, and mercury concentrations as the water moves past the Pilot Study Area from upriver to downriver. However, these changes

are comparable to baseline conditions and illustrate the inherent variability of water column measurements and suspended sediment transport.

- On December 6, 2005, the integrated samples were collected during an ebb tide as dredging was being performed in the 11-foot MLW cut. In the suspended-phase, there appears to be an increase in the 2,3,7,8-TCDD, Total DDT, Total PCB, lead, and mercury concentrations as the water moves past the Pilot Study Area from upriver to downriver. However, these changes are comparable in magnitude to other observations (refer to discussion for December 10, 2005) and are considered to represent baseline variability and not sediment resuspension associated with the dredging operation.
- On December 7, 2005, only one set of integrated samples was collected during a flood tide as dredging was being performed in the 15-foot MLW cut. In the suspended-phase, there appears to be a slight decrease in the 2,3,7,8-TCDD, Total DDT, Total PCB, and mercury concentrations and a slight increase in the lead concentration as the water moves past the Pilot Study Area from downriver to upriver. However, these differences are comparable to baseline conditions.
- On December 8, 2005, only one set of integrated samples was collected during a flood tide as dredging was being performed in the 15-foot MLW cut. In the suspended-phase, there appears to be an increase in the 2,3,7,8-TCDD and lead concentrations and decrease in the Total DDT, Total PCB, and mercury concentrations as the water moves past the Pilot Study Area from downriver to upriver. Both the lack of consistent direction of change and the level of variation would indicate that these differences represent baseline conditions and not dredging-related releases.
- On December 10, 2005, one set each of integrated samples was collected during an ebb tide and a flood tide. In the morning, samples were collected during an ebb tide as dredging was being performed in the 15-foot MLW cut. In the suspended-phase, there appears to be a decrease in the 2,3,7,8-TCDD, Total DDT, Total PCB, and lead concentrations and almost no change in the mercury concentration as the water moves past the Pilot Study Area from upriver to downriver. In the afternoon, samples were collected during a flood tide. In the suspended-phase, concentrations for 2,3,7,8-

TCDD, Total DDT, Total PCB, and lead appear to increase while the mercury concentration decreases as the water moves past the Pilot Study Area from downriver to upriver. Again, these differences are considered consistent with baseline variations and do not indicate substantive dredging-related releases of contaminated sediment.

9.0 CONCLUSIONS

The Environmental Dredging Pilot Study (referred to as the Pilot Study) was conducted to support the remedial investigation and feasibility study for the Lower Passaic River Restoration Project, which is an interagency study being performed to develop an approach to remediating and restoring the Lower Passaic River. The Pilot Study was conducted in accordance with approved project plans, including the Work Plan, Quality Assurance Project Plan, and Health and Safety Plan (TAMS/ET and Malcolm Pirnie, Inc., 2005a). These plans and additional documents can be found on the public website www.ourpassaic.org.

9.1 SUMMARY OF THE PILOT STUDY

The Pilot Study was designed to yield information on dredging performance and resuspension associated with production environmental dredging, operating with one mechanical dredge system. The Pilot Study was conducted between December 5, 2005 and December 10, 2005 on the Lower Passaic River and involved the removal of approximately 4,000 ±200 cubic yards of dredged material from an area covering 1.2 acres (approximate dimensions of 170 feet wide by 290 feet long). The project was designed to target elevations of 11 feet MLW, 13 feet MLW, and 15 feet MLW. The major objectives of the Pilot Study, which are specific to the dredging technology tested and the site examined, include:

- Evaluate dredging equipment performance: This objective includes productivity, vertical accuracy (achieving targeted dredging depth and cut lines) and operational controls.
- Monitor sediment resuspension: This objective includes an evaluation of how much sediment and associated contamination are resuspended or otherwise released by the dredging operation.

The data collected during the Pilot Study were used to evaluate dredge performance, productivity, and sediment resuspension associated with an environmental dredging demonstration. The Pilot Study data are site-specific to the Lower Passaic River and may not be fully representative of the physical and environmental conditions under which a full-scale dredging operation may be conducted. However, the results of the Pilot Study help form a basis from which assumptions for a full-scale dredging operation can be made. The scalability of the data and their applicability to a full-scale dredging operation should be evaluated as it is incorporated into other documents. The feasibility study for the Lower Passaic River as well as the *Focused Feasibility Study for the Lower Eight Miles of the Lower Passaic River* (The Louis Berger Group, Inc., anticipated December 2012) will incorporate the Pilot Study results as well as other literature data to develop a general approach for a full-scale dredging operation.

The decontamination demonstration aspect of the Pilot Study, which included an assessment of treatability and beneficial use of contaminated sediment, was implemented by USEPA and NJDOT under the New Jersey-New York Harbor Sediment Decontamination Technology Demonstration Program. The decontamination vendor reports were published under separate cover by others and are currently available on the public website www.bnl.gov/wrdadcon.

9.2 SUMMARY OF DREDGE EQUIPMENT PERFORMANCE

The Pilot Study was designed to yield information regarding the operational controls, productivity, and vertical accuracy associated with production environmental dredging. Optimal dredging operations with minimal resuspension were achieved on December 7-8, 2005 and December 10, 2005 by employing Best Management Practices, which included:

- Operating with an environmental clamshell bucket.
- Optimizing the environmental bucket cycle time between grabs by adjusting horizontal transfer speed while underwater, lift speed through the water column, and hang-time above the river.
- Using two passes per dredge swing arc to achieve target depth.

- Optimizing the use of winching and cabling in place of tugboats for repositioning the rinse tank.

With these operational controls, the dredge operated with an average cycle time of 2.5 minutes and typical daily cycle times ranged from an average of 1.55 to 3.20 minutes. It was estimated that the rinse tank, used to clean the dredge bucket between each cycle, accounted for approximately a 30-second component of the cycle time. However, this time period varied depending on the placement of the rinse tank barge (*i.e.*, tugboat assisted positioning versus stationary positioning). Tugboat-assisted positioning of the rinse tank barge reduced the overall cycle time since this method reduced the time required to extend the dredge arm to reach the tank; however, the resuspension of sediment associated with the tugboat operation was noticeable. Stationary positioning of the rinse tank barge slowed the dredging operation and added time to the overall cycle time. Furthermore, the study concluded that a rinse tank was not worthwhile given minimal sediment recovery (approximately 0.3 percent of volume dredged) during the dredging activities.

The Pilot Study operated with an average work day of 10.5 hours/day, which represents the total hours on the site as determined from the Jay Cashman, Inc. field logs. However, to achieve the objectives of the Pilot Study, client-directed standby was required to allow for alignment of the dredging activity with the resuspension monitoring activities. After accounting for client-directed standby time and lost time, the average work day was 8.3 hours/day. The ratio of the effective working time to the dredging time (or the EWTE, which is commonly referred to as the "uptime") was 60 percent for the entire Pilot Study. While this uptime is typical for mechanical dredging operations in the New York Harbor region (USACE, 2006), the Pilot Study involved the testing of different operational controls and Best Management Practices. Consequently, the presentation of an average uptime value does not accurately represent the Pilot Study. The EWTE for the first two days of the Pilot Study was 45 percent, which is lower than the uptime range (55 to 70 percent) that is typical for sediment remediation projects (USACE, 2008a) and is directly associated with the project shakedown. However, the EWTE for the remainder of the

Pilot Study was 79 percent, which is higher than the typical environmental dredging range and actually resembles ranges typically seen for navigation dredging nationwide (70 to 85 percent; USACE, 2008a).

Similar to the work time analysis, productivity rates were calculated to reflect days when dredging techniques were being tested (December 5-6, 2005) as opposed to days when Best Management Practices and operational controls were optimized (December 7-8 and 10, 2005). The maximum operating production rate for the first two days of the Pilot Study was 200 cubic yards/hour; however, this rate decreased to 130 cubic yards/hour later in the Pilot Study when Best Management Practices were optimized. Productivity decreased when Best Management Practices were implemented because these practices yielded longer cycle times and less volume removed per dredge.

In contrast to the maximum production rate, the average operating production rate increased from 90 cubic yards/hour for the first two days of the Pilot Study to 100 cubic yards/hour later in the Pilot Study when Best Management Practices were optimized. The increase in average operating production rate reflects the change in the effective working time over the course of the Pilot Study and the increase in the uptime from 45 percent at the beginning of the Pilot Study to 79 percent later in the Pilot Study. These rates are mathematically equivalent to the removal of 2,200 cubic yards and 2,500 cubic yards of dredge material (respectively) over a 24-hour period. Note that this mathematical conversion does not represent a production rate across a full operating season, nor does it incorporate impacts from clean-up passes or constraints on allowable times for dredging due to operational and quality of life issues. It should also be noted that during a full-scale operation, more routine maintenance may be required to account for the "wear and tear" on dredging equipment that is associated with a longer work day; increased routine maintenance would subsequently reduce the uptime.

The dredging accuracy with this productivity rate indicates that first-pass dredging projects executed in the Lower Passaic River could be expected to achieve an accuracy of ±12 inches more than 90 percent of the time and ±6 inches more than 70 percent of the time. The use of computerized dredge bucket positioning systems improved dredging accuracy.

9.3 SUMMARY OF RESUSPENSION AND SUSPENDED SEDIMENT FLUX

Monitoring programs (consisting of mooring-based data collection and direct water column sampling) were conducted to monitor the resuspension of sediment associated with the dredging activities. Data were collected in the far-field (approximately 1,000 feet from the dredging operations), the near-field (approximately 400 feet from the dredging operation), and in the very near-field (area between the inner moorings and the dredging operation; approximately 60 feet to 300 feet) to determine how much resuspended sediment was exported beyond the immediate vicinity of the dredging operations.

At the far-field locations, three different methods were examined (using mooring data and integrated boat-based samplers) to estimate the amount of suspended sediment transport due to dredging activities. In each instance, the results of the evaluation indicated that during the Pilot Study the amount of suspended sediment carried by the river dwarfed any suspended sediment flux due to dredging. Instantaneous water column suspended sediment concentrations varied by more than two orders of magnitude within a single tidal cycle. Even time-averaged estimates of baseline (*i.e.*, upflow) suspended sediment transport varied more than an order of magnitude and were clearly subject to natural variability and measurement uncertainty. In all three methods used to estimate suspended sediment transport, downflow measures of the suspended sediment flux were considered to be equal to the upflow suspended sediment flux, given natural variability and measurement uncertainty. Consequently, no reliable estimate of the far-field suspended sediment flux could be obtained.

In the near-field, a principal component analysis was performed on the upriver and downriver LISST particle size distribution data. This tool was unable to separate or differentiate the upriver and downriver data, suggesting that variation in the particle size distribution is unrelated to the dredging operation or flow direction in the tidal cycles in the near-field. Like the observations of suspended sediment flux in the far-field, observation with the particle size data in the near-field suggest that the local resuspension in the river provides the vast majority of suspended sediment in the water column, making it difficult to accurately quantify the impact of sediments resuspended by dredging. Ultimately, the data suggest that the particle size distribution in the water column at the time of the Pilot Study was insensitive to the dredging-related resuspension. This insensitivity may be related to several issues including the possible similarity of the particle size distribution for both naturally and dredging-related resuspension but is more likely due to the relatively small increase in the net suspended sediment flux due to dredging.

In the very near-field, two evaluations were completed to evaluate dredge-related resuspension. These evaluations included a harmonic analysis on mean flow and tidal current velocity data as well as an integration of two-dimensional estimated TSS. The results of these evaluations indicate that dredge-related resuspension is detectable in the very near-field, despite a wide variation in the background suspended sediment load. However, this signal is apparently rapidly dissipated since it is not readily discernable in the near-field (approximately 400 feet from the dredging operation).

The very near-field observations were sufficient to demonstrate the effectiveness of Best Management Practices. Relatively lower percent resuspension (2 percent) was observed in the very near-field on December 7, 2005 and December 8, 2005 when Best Management Practices and operational controls were optimized. A storm event on December 9, 2005 is likely responsible for the large suspended sediment flux variations (4 percent) observed on December 10, 2005 even though Best Management Practices were in place. The high degree of the variability in the suspended sediment flux for that day is likely evidence of the storm's impact. Conversely, relatively higher percent resuspension (6 percent) was observed in the very near-field during the first two days of the Pilot Study when dredging techniques were being tested and maximum operating production rates were higher (200 cubic yards/hour).

While this analysis did provide an estimate of the dredging-related suspended sediment flux in the very near-field, it is considered an upper bound on the amount of suspended sediment that might escape to the far-field since flocculation and settling are expected to substantively reduce this flux downflow. Moreover, this signal is not discernable from background at the near-field distance of 400 feet, indicating that dredge-related solids settle out of the water column or are dispersed between the very near-field and the near-field. Some of these solids may subsequently combine with the regularly suspended sediments layer and may be transported with the tidal currents. Dredging-related resuspension at the far-field could not be discerned above baseline suspended sediment transport, indicative of the relatively small increase in the suspended sediments caused by the dredging operation relative to the natural suspended sediment load carried by the river.

10.0 ACRONYMS

2,3,7,8-TCDD	2, 3, 7, 8-tetrachlorodibenzo-p-dioxin
2,4-D	2,4-Dichlorophenoxyacetic acid
2,4,5-T	2,4,5-Trichlorophenoxyacetic acid
ADCP	Acoustic Doppler Current Profiler
ASTM	American Society for Testing and Materials
Bottom	meter above river bottom (acronym listed in tables)
CARP	Contaminant Assessment and Reduction Project
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFD	Computational Fluid Dynamics
CFR	Code of Federal Regulations
CLP	Contract Laboratory Program
cm/s	centimeter per second
CTD	Conductivity-Temperature-Depth
cy	cubic yard (acronym listed in tables)
cy/hr	cubic yard per hour (acronym listed in tables)
D_{50}	Average Median Particle Diameter
DDD	4,4'-dichloro-diphenyl-dichloro-ethane
DDE	4,4'-dichloro-diphenyl-dichloro-ethylene
DDT	4,4'-dichloro-diphenyl-trichloro-ethane
DESA	Division of Environmental Science and Assessment
DGPS	Differential Global Positioning System
DOC	Dissolved Organic Carbon
Elev	Elevation (acronym used in figures)
EMPC	Estimated Maximum Possible Concentration
EST	Eastern Standard Time
EWTE	Effective Working Time Efficiency
ft	feet (acronym used in figures)

ft^3/s	cubic feet per second
GFF	Glass Fiber Filters
GIS	Geographic Information System
GMT	Greenwich Mean Time
GPS	Global Positioning System
HASP	Health and Safety Plan
HAZWOPER	Hazardous Waste Operations and Emergency Response
HT	High Tide (acronym used in figures)
kg	kilogram (acronym listed in tables)
kg/m^3	kilogram per cubic meter (acronym listed in tables)
kg/s	kilogram per second
L	liters (acronym listed in tables)
LISST	Laser *In-Situ* Scattering and Transmissometry
LT	Low Tide (acronym used in figures)
m	meter (acronym used in figures)
m^3	cubic meter (acronym listed in tables)
m^3/cy	cubic meters per cubic yard (acronym listed in tables)
m^3/s	cubic meters per second
mg	milligram
mg C/L	milligram of carbon per liter
mg C/g	milligram of carbon per gram
mg/kg	milligram per kilogram
mg/L	milligram per liter
MHW	Mean High Water
min	minute (acronym listed in tables)
min/hr	minute per hour (acronym listed in tables)
MLW	Mean Low Water
mm	millimeter (acronym used in figures)
mph	miles per hour
MS	Microsoft

MSL	Mean Sea Level (acronym used in figures)
N/A	Not Available (acronym listed in tables)
NELAC	National Environmental Laboratory Accreditation Conference
ng/kg	nanogram per kilogram (acronym listed in tables)
ng/L	nanogram per liter
NGVD29	National Geodetic Vertical Datum 1929
NJDEP	New Jersey Department of Environmental Protection
NJDOT	New Jersey Department of Transportation
NJGIN	New Jersey Geographic Information Network (acronym used in figure)
NOAA	National Oceanic and Atmospheric Administration
NTU	Nephelometric Turbidity Units (acronym listed in tables)
OBS	Optical Backscatter Sensor
OCC	Occidental Chemical Corporation
OSHA	Occupational Safety and Health Administration
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PCDD/F	Polychlorinated Dibenzodioxin/Furan
PFDs	Personal Flotation Devices
pg/L	picogram per liter (acronym listed in tables)
POC	Particulate Organic Carbon
PSU	Practical Salinity Units (acronym listed in tables)
PVSC	Passaic Valley Sewerage Commissioners
QA	Quality Assurance (acronym used in figures)
QAO	Quality Assurance Officer
QAPP	Quality Assurance Project Plan
RM	River Mile
RPD	Relative Percent Difference
RTK	Real Time Kinematic
SOPs	Standard Operating Procedures

S/m	Siemens per Meter (acronym listed in tables)
s/min	second per minute (acronym listed in tables)
SPI	Sediment Profile Imaging
STL-OH	Severn Trent Laboratories in North Canton, Ohio
STL-TN	Severn Trent Laboratories in Knoxville, Tennessee
STL-VT	Severn Trent Laboratories in Burlington, Vermont
SVOC	Semivolatile Organic Compounds
TAL	Target Analyte List
TAMS/ET	TAMS Consultants, Inc., *an Earth Tech Company*
TCL	Target Compound List
TD	downriver TOPS boat
TOC	Total Organic Carbon
Top	meter below river water surface (acronym listed in tables)
TOPS	Trace Organic Platform Sampler
Total TCDD	Total Tetrachlorodibenzodioxin
TPH	Total Petroleum Hydrocarbons
TSA	the 'A' leg of traverse
TSI	Tierra Solutions, Inc.
TSS	Total Suspended Solids
TU	upriver TOPS boat
URRI	Urban River Restoration Initiative
USACE	United States Army Corps of Engineers
USCS	Unified Soil Classification System
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geologic Survey
VOC	Volatile Organic Compounds
WRDA	Water Resource Development Act
XAD	XAD-2 polystyrene exchange resin
º F	Degrees Fahrenheit

º C/F	Degrees Celsius or Fahrenheit (acronym listed in tables)
μm	micron (acronym used in figures)
μg/kg	microgram per kilogram
μL/L	microliter per liter

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Table 1-1: Pilot Study Crew List

Task/Role	Personnel	Company/Agency at the time of implementation
Overall Project Management	Lisa Baron[1]	NJDOT
	Maheyar Bilimoria[2]	Earth Tech, Inc.
	Scott Thompson [3]	Malcolm Pirnie, Inc.
NJDOT Dredging Specifications	Lisa Baron[1]	NJDOT
	Michael Palermo	Mike Palermo Consulting
	Donald Hayes	University of Utah
	Scott Thompson [3]	Malcolm Pirnie, Inc.
	Maheyar Bilimoria[2]	Earth Tech, Inc.
	Steve Weinberg	USACE
	Scott Douglas	NJDOT
	April Thomman	Earth Tech, Inc.
	John Szeligowski	Earth Tech, Inc.
Inter-Agency Selection Panel for Dredger	Lisa Baron[1]	NJDOT
	Scott Douglas	NJDOT
	Eric Stern	USEPA
	Steve Weinberg	USACE
	Michael Palermo	Mike Palermo Consulting
	Donald Hayes	University of Utah
Dredging Team	Steve Radel	Jay Cashman, Inc.
	Bruce Wood	
	Richie Barber	
	Mike Lewis	
	Anthony Kerley	
	Anthony Carbone	
	Harry Ellis	
	Carl Stewart	
	Jimmy Bauer	
	Dan Gaudet	
	Ray Bergeron	Cable Arm, Inc.
	Darrell Nicholas	
	Sam Harrell	
	John Lajeuanesse	
	Connie Boris	
	Gerald Swain	
	Harry Steves	
Dredging Construction Oversight	Michael Kucera	USACE
	Shewen Bian	
	Ron Connetta	
	Lisa Swan	Earth Tech, Inc.

Table 1-1: Pilot Study Crew List

Task/Role	Personnel	Company/Agency at the time of implementation
Water Quality Sampling Team	Robert Chant	Rutgers University
	Chip Haldeman	
	Dave Fugate	
	Eli Hunter	
	Dan Crowell	
	John Zlotnik	
	Tim Wilson	USGS
	Jennifer Bonin	
	Nicholas Smith	
	Ed Garvey [3]	Malcolm Pirnie, Inc.
	Len Warner [3]	
	Liam Bossi	
	Erika Zamek [3]	
	David Foster	
	John Peake	
	David Lewitt	
	John Mulligan [3]	
	Jason Fuller	
	Jermaine Perry	
	Solomon Gbondo-Tugbawa [3]	
	Andrew Schell	
	Maheyar Bilimoria[2]	Earth Tech, Inc.
	Robert Forstner	
	Sameer Ahsan	
	Amit Haryani	
	Roman Senyk	
	Edward Sitler	
	Muhammad Akbar	
General Field Oversight	Lisa Baron[1]	NJDOT
	Peter Weppler	USACE
	Maheyar Bilimoria[2]	Earth Tech, Inc.
	Scott Thompson [3]	Malcolm Pirnie, Inc.
Boat Captains	Richard Henry	USFWS
	Gene Nieminen	
	Jim Nickels	AquaSurvey, Inc.
	Mike Marcello	USACE
	Michael McGuire	
Chain of Custody	Celeste Foster	Earth Tech, Inc.
	John Rollino	
	Florence Rollino	

Table 1-1: Pilot Study Crew List

Task/Role	Personnel	Company/Agency at the time of implementation
Chemical Analysis	Jennifer Ferranda	USEPA
	John Birri	USEPA
	Allen Burton	Earth Tech, Inc.
Predictive Hydrodynamic Modeling	Ryan Edison	Earth Tech, Inc.
	Serkan Mahmutoglu	
Health and Safety Officer	Chris Purkiss [3]	Malcolm Pirnie, Inc.
Permitting	Suzanne Dietrick	NJDEP
	David Risilia	
	Richard Tomer	USACE
Decontamination Technology Coordination	Eric Stern	USEPA
	Scott Douglas	NJDOT
	John Sontag	BioGenesis
	Mike Mensinger	Endesco Clean Harbors
	Valerie Montecalvo	Bayshore Recycling
	Frank Montecalvo	
Landside Staging Area/Access Coordination	Brian Davenport	PVSC
	Sheldon Lipke	
	Bob DeVita	
LPR Project Coordination	Alice Yeh	USEPA
	Peter Weppler	USACE
	Scott Nicholson	
	Janine McGregor	NJDEP
	Reyhan Mehran	NOAA
	Tim Kubiak	USFWS

1. Currently employed at the United States Army Corps of Engineers.
2. Currently employed at Tetra Tech, Inc.
3. Currently employed at The Louis Berger Group, Inc.

NJDEP= New Jersey Department of Environmental Protection
NJDOT= New Jersey Department of Transportation
NOAA= National Oceanic and Atmospheric Administration
PVSC= Passaic Valley Sewerage Commissioners
USACE= United States Army Corps of Engineers
USEPA= United States Environmental Protection Agency
USFWS= United States Fish and Wildlife Service
USGS= United States Geological Survey

Table 2-1: Bridge Clearance and Notice Requirements

Bridge [1,2]	Water Body Location	Type	Horizontal	Vertical Clearance (feet at high water)	Notice Required
Garden State Parkway (Driscoll Bridge)	Raritan River	Fixed	199	135	N/A
Route 9 Edison Bridge	Raritan River	Fixed	250	135	N/A
Victory Bridge	Raritan River	Swing	440	130	N/A
Conrail	Raritan River	Swing	125	8	on signal
Outer Bridge Crossing	Arthur Kill	Cantilever	675	143	N/A
Goethals Bridge	Arthur Kill	Cantilever	672	135	N/A
Railroad Bridge to Bayway Barge Piers	Arthur Kill	Lift	500	31 Down/135 Up	on signal
New Jersey Turnpike Extension	Newark Bay	Bay Fixed	550	135	N/A
Conrail	Newark Bay	Lift	300	35 Down/135 Up	on signal
Central Railroad of New Jersey	Lower Passaic River	Swing	100	25	Removed
Lincoln Highway Bridge (Routes 1&9)	Lower Passaic River	Lift	300	40 Down/135 Up	4 hours
Pulaski Skyway	Lower Passaic River	Fixed	520	135	N/A
Point-No-Point Conrail (freight bridge)	Lower Passaic River	Swing	103	16	4 hours
New Jersey Turnpike	Lower Passaic River	Fixed	319	100	N/A
Jackson Street Bridge	Lower Passaic River	Swing	75	15	4 hours
Northeast Corridor (Amtrak)	Lower Passaic River	Lift	200	24 Down/138 Up	4 hours

Notes:
1. There are also a number of overhead power cables ranging from 135 to 170 feet vertical clearance.
2. Information obtained from navigational charts 21st edition and 33 CFR 117.
N/A= Not Available

Table 3-1: Concentration Ranges and Averages for the Contaminants of Concern and Total Organic Carbon Data from Sediment Coring Program, July 2004

Parameter	0 to 1 foot interval				1 to 2 foot interval				2 to 3 foot interval				0 to 3 foot composite (Note 3)			
	Det/n	Minimum	Maximum	Average	Det / n	Minimum	Maximum	Average	Det / n	Minimum	Maximum	Average	Det / n	Minimum	Maximum	Average
Organics (µg/kg)																
2,3,7,8-TCDD	5/5	0.29	0.63	0.46	5/5	0.29	0.72	0.53	5/5	0.37	1.90	1.27	15/15	0.29	1.90	0.75
Total PCB (Congeners)	5/5	366	531	428	5/5	967	1,098	1,031	5/5	1,702	2,472	2,139	15/15	366	2,472	1,199.33
Total PCB (Aroclors) from STL	5/5	1,100	1,920	1,656	5/5	2,330	3,800	3,346	5/5	5,100	7,400	6,600	15/15	1,100	7,400	3,867.33
Total PCB (Aroclors) from CLP/DESA	6/15	ND	470	136	10/15	ND	2,800	543	9/15	ND	5,100	1,193	25/45	ND	5,100	624.00
Total PAH (Note 1)	3/15	ND	35,820	6,848	8/15	ND	40,210	13,500	14/15	ND	66,500	29,910	25/45	ND	66,500	16,752.67
Total DDT (4,4'-isomer only)	15/15	59	1,100	195	15/15	46	246	105	15/15	53	379	165	45/45	46	1,100	155.00
Metals and TOC (mg/kg)																
Lead	15/15	210	330	281	15/15	320	560	451	15/15	450	1,100	647	45/45	210	1,100	459.67
Mercury	15/15	1.7	3.5	2.3	15/15	2.6	5.5	4.2	15/15	2.8	12	5.1	45/45	1.7	12.0	3.87
Total Organic Carbon	15/15	49,000	70,000	56,500	15/15	46,000	63,000	53,700	15/15	45,000	81,000	59,300	45/45	45,000	81,000	56,500

Parameter	3 to 4 foot interval			
	Det/n	Minimum	Maximum	Average
Organics (µg/kg)				
2,3,7,8-TCDD	5/5	1.4	2.5	1.9
Total PCB (Congeners)	5/5	3,054	3,530	3,365
Total PCB (Aroclors) from STL	5/5	8,400	12,200	9,600
Total PCB (Aroclors) from CLP/DESA	8/8	400	780	550
Total PAH (Note 1)	8/8	6,299	10,660	7,993
Total DDT (4,4'-isomer only)	8 / 8	30	48	37
Metals and TOC (mg/kg)				
Lead	8 / 8	540	850	631
Mercury	8 / 8	5.4	7.8	6.8
Total Organic Carbon	8 / 8	46,000	68,000	53,500

Notes:

1. Total PAH is the sum of the 17 standard PAH compounds. The 3-4 foot samples were also analyzed for 7 additional PAH compounds (refer to the Final Data Summary and Evaluation Report, Table 4-3C); which added 1,000 to 1,600 µg/kg to the total.
2. The 3-4 foot samples were analyzed by commercial laboratory (5 samples by STL) and DESA (8 samples).
3. Data for "0 to 3 foot composite" is derived mathematically from the data for individual 1-foot sections.
4. Aroclor analyses on the 15 samples from each 1-foot interval in 0-3 feet range were analyzed by a CLP laboratory (Mitkem).
5. For averaging purposes, non-detected concentrations were incorporated into the summations as zero.
6. Depth interval measured from top of sediment/water interface.
7. "Det" is number of detections; "n" is total number of data points (includes duplicates and validated and unvalidated data).
8. ND in "Minimum value" indicates analyte was not detected in one or more samples in this group.
9. Data from samples collected July 2004.

mg/kg= milligram per kilogram
µg/kg= microgram per kilogram

Table 4-1: Vessel Specifications

Vessel Type	Vessel Name	Length	Width or Beam	Depth	Gross Tonnage	Year	Other Specifications
Rinse Tank Barge		90 feet	30 feet	not available	not available	not available	No technical specifications available (communicaton with Steve Raedel); rinse tank was custom welded (rinse tank dimensions= 18 feet long × 14 feet wide × 9 feet deep) to fit the environmental (8 cubic yard) clamshell bucket.
Hopper Barge ("scow")	SEI 3000	260 feet	52.6 feet	12 feet	1375 tons	1982	Refer to brochure in Appendix C.
Hopper Barge ("scow")	SEI 3003	260 feet	52.6 feet	12 feet	1375 tons	1982	Refer to brochure in Appendix C.
Guide Barge	SEI 32	250 feet	38 feet	10 feet	855 tons	not available	Refer to brochure in Appendix C. Spud Number = Three (50 feet).
Dredge	Wood I	134 feet	50 feet	11 feet	681 tons	not available	Refer to brochure in Appendix C. Crane Model = 2400 Lima Crane Boom = 100 feet / 120 feet Cable size = 1.5 inch Linepull = 136,000 pounds Spuds = Three (30 inch × 90 feet) Spud Wells = Three (32 inch) Winches = 60,000 pounds/linepull 250 Horsepower
Crew Boat & Tug Boat	Alex D	38 feet	14 feet	6.5 feet	26 tons	1982	Refer to brochure in Appendix C. 500 Horsepower Twin Screws.
Tug Boat	Dorothy	100	not available	not available	not available	1951	Refer to brochure in Appendix C. 1800 Horsepower Single Screw
Tug Boat	Vernick	100	not available	not available	not available	not available	According to Jay Cashman, Inc., the Vernick tug boat has the same specifications as the Dorothy tug boat.
Tug Boat	Uncle George	66 feet	24 feet	6.5 feet	91 tons	not available	Refer to brochure in Appendix C. 3400 Horsepower Twin screw Conducted initial movement of equipment.

Table 4-2: Redox Potential Discontinuity Depths Measured by Sediment Profile Imaging

Location	Average Redox Potential Discontinuity Depth (centimeter)
December 2005 – Inside Sediment Coring Grid	
A1	5.4
C1	9.9
E1	3.5
A2	7.3
C2	6.7
E2	5.7
A3	4.6
C3	6.2
E3	4.5
Average	**6.0**
December 2005 – Outside Sediment Coring Grid	
A1-West	9.0
A3-West	17.8
B1-North	0.7
D1-North	0.6
E1-East	2.3
E3-East	6.7
Average	**6.2**
June 2005 – Upriver and Downriver Transects	
SPI-126	4.0
SPI-127	0.4
SPI-128	0.2
SPI-129	2.2
SPI-130	1.6
SPI-131	0.9
SPI-132	2.6
SPI-133	1.5
SPI-134	2.1
SPI-135	1.4
Average	**1.7**

Notes:

1. Refer to Figure 4-2 and Figure 4-3 for map of Sediment Profile Imaging locations.

Table 5-1: Weather Data for Newark, New Jersey

Date	Temperature Average ($^oC/^oF$)	Wind Speed Average (miles per hour)	Wind Direction
December 5, 2008	0.4/32.7	2.3	West-Southwest
December 6, 2008	0.5/32.9	5.3	West-Northwest
December 7, 2008	-1.8/28.7	7.7	West
December 8, 2008	-2.4/27.7	5.2	West-Southwest
December 9, 2008	-0.1/31.9	6.9	West-Northwest
December 10, 2008	-1/30.3	4.9	South

Source: Weather Underground, www.wunderground.com

$^oC/^oF$= Degrees Celsius or Fahrenheit

Table 5-2: Field Notes from the Pilot Study (Compiled by Field Oversight Engineer)

Date [1]	Section/ Dredge Cells	Station	Total Dredge Time (Hours)	In-Situ Daily Volume Estimate (cy) [2]	Scow	Daily Ullage Scow Sediment Volume Estimate (cy) [3]	Estimated Production Time (cy/hr) [4]	Estimated Average Cycle Time (minute:seconds)	Rinse Tank Sediment Estimates [5]	Variations from approved Work Plan	Operational changes in Dredge Technique	Other Considerations
December 5, 2005	13' / Cells A2 -E2	0+05 - 2+77	7.25	942.26	SEI 3000	932.29	130	1:45	Clean Water - no measurement taken	ClamVision© depth and bucket closure systems not operational. Bucket chain marking method was used to estimate depth of sediment removal, based on operator judgment. Several overfilled buckets were observed during this period. Full depth of sediment removal was consistently achieved through one bucket pass in each dredge swing arc.	From 13:35 - end of shift, (Stas. 0+71 - 0+277), the Alex D tug was used to guide the rinse tank in order to minimize crane boom extensions. The sampling teams reported increased turbidity readings during this operation.	
December 6, 2005	11' / Cells A3 -C3	0+05 - 2+05	7.68	1012.28	SEI 3000	608.02	178	2:20	7.2 feet water, no measurable sediment; two buckets removed.	ClamVision© depth and bucket closure systems not operational. Bucket chain marking method was used to estimate depth of sediment removal, based on operator judgment. Several overfilled buckets were observed during this period. Full depth of sediment removal was consistently achieved through one bucket pass in each dredge swing arc.	Continued to use Alex D tug to guide the rinse tank.	Scow SEI 3000 transported to BioGenesis Washing BGW, LLC @ 16:50 hrs. Increased tug activity during this period.
December 6, 2005	11' / C3 - E3	2+05 - 2+77		354.28	SEI 3003	162.14		2:50		Full depth of sediment removal was consistently achieved through one bucket pass in each dredge swing arc.	ClamVision© depth and bucket closure systems fully operational at 17:35 hrs, (Cell D-3, Sta 2+00) which increased cycle time due to operator orientation of the system. Less frequent overfilled buckets were observed upon full operation of the depth sensor equipment.	Real-time Clam Vision data will provide more accurate cycle times. From 19:30-20:30 the dredge was moved to the 15' section, guide barge dismantled and rinse tank relocated to port side of dredge. Increase tug activity during this period.
December 7, 2005	15' / A1 - B1	0+05 - 1+25	7.16	833.69	SEI 3003	608.02	116	2:18	7 feet water, sediment less than 6 inches; two buckets removed	None noted	Rinse tank was moved to the port side of the dredge. Tug boat assistance no longer used to guide rinse tank. From 08:35 - 13:12 (Sta 0+00 - 0+64) operator revised dig technique by taking two passes per arc to achieve design depth. Observed increase in decant water in scow, however drain water was much less turbid. From 13:15 - 15:40 (Sta 0+64 - 1+28) operator revised dig technique by taking one paa per swing arc to achieve design depth, with ~ 1/4 bucket overlap. Observed few over-filled buckets and decant water was much more turbid.	Real-time Clam Vision data will provide more accurate cycle times.

Table 5-2: Field Notes from the Pilot Study (Compiled by Field Oversight Engineer)

Date [1]	Section/ Dredge Cells	Station	Total Dredge Time (Hours)	In-Situ Daily Volume Estimate (cy) [2]	Scow	Daily Ullage Scow Sediment Volume Estimate (cy) [3]	Estimated Production Time (cy/hr) [4]	Estimated Average Cycle Time (minute:seconds)	Rinse Tank Sediment Estimates [5]	Variations from approved Work Plan	Operational changes in Dredge Technique	Other Considerations
December 8, 2005	15' / B1-D1	1+25 - 2+00	4.43	486.31	SEI 3003	445.9	110	2:42	6.5 feet water; approx. 1 foot sediment; two buckets removed	None noted	Dredge technique included taking two passes per swing arc to achieve design depth. Observed increase in decant water in scow, however drain water was much less turbid.	Real-time Clam Vision data will provide more accurate cycle times.
December 10, 2005	15'/ D1-E1	2+00 - 2+85	5.25	521.52	SEI 3003	363.8	99	2:00	6.5 feet water; approx. 1 foot sediment; two buckets removed	None noted	Dredge technique included taking two passes per arc to achieve design depth. Observed increase in decant water in scow, however drain water was much less turbid. Bucket drain "hang" time was increased to allow complete decanting in water column prior to dumping.	Real-time Clam Vision data will provide more accurate cycle times.

Notes:

1. No dredging was performed on 12/9/05 due to inclimate weather conditions.

2. Theoretical in-situ sediment removal volumes based on intermediate survey data performed by Jay Cashman, Inc. (JCI). Volumes were calculated by comparing post excavation survey after each dredge day versus pre-condition survey performed by Roger's (dated 11/28/05).

3. Ex-situ scow sediment volumes are based on a average of six depth soundings to sediment surface, freeboard water is not included in this estimate (see JCI daily Ullage reports).This method of of meaurement is considered highly subjective due to variation of measurements on a daily basis due to the load shifting between daily scow movement.

4. Production rates calculated based on in-situ sediment volume estimates (cy)/total dredge time (hours), as determined by intermediate survey data.

5. Based on visual observation - approximately 2 cy /day of rinse water was removed from the tank.

6. Daily dredge and sediment scow movements are presented on the daily JCI reports. It should be noted that the daily displacement tonnage is a measurement of the dispacment of water caused by the load and does not directly relate the the sediment volume. In order to guage an accurate tonnage of material transported in a scow it would necessary to obtain an accurate bulk density of the material.

cy= cubic yard
cy/hr= cubic yards/hour

Table 5-3: Summary of Daily Cycle Time

	FIELD OBSERVATIONS	CLAMVISION DATA					JAY CASHMAN, INC. VIDEO LOGS		
Date	**Estimated Average Daily Cycle Time (minute)[1]**	**Average Daily Cycle Time - All Data (minute)[2]**	**Median of All Data (minute)**	**Average Daily Cycle Time - Screened Data (minute)[3]**	**Median of Screened Data (minute)**	**Range of Typical Cycle Time (minute)[4]**	**Average Daily Cycle Time (minute)**	**Median of All Data (minute)**	**Operational Characteristics**
December 5, 2005	1.75	1.99	1.98	2.11	2.03	1.5 - 3	2.30	2.10	Cable Arm, Inc. sensors not working; used bucket chain method, single lift per area, no extended equilibration time.
December 6, 2005 (before 1735 hours EST)	2.33	2.04	2.14	2.26	2.17	1.5 - 3	N/A	N/A	Cable Arm, Inc. sensors not working until 1735 hours EST; used bucket chain method, single lift per area, no extended equilibration time.
December 6, 2005 (after 1735 hours EST)	2.83	1.07	1.05	1.35	1.15	0.75 - 2	N/A	N/A	
December 6, 2005 (all day)	N/A	1.74	1.98	2.01	2.07	0.75 - 2.75	2.49	2.39	
December 7, 2005	2.30	2.51	2.63	2.73	2.67	2 - 3.5	3.04	2.98	2 lifts per area
December 8, 2005	2.70	2.80	2.90	2.89	2.93	2 -3.5	2.81	2.83	2 lifts per area
December 9, 2005	No Dredging								Not applicable
December 10, 2005	2.00	2.64	2.48	2.57	2.55	1.5 - 3.25	3.16	2.77	2 lifts per area, extended bucket equilibration time.
Day Average	**2.32**	**2.34**	**2.40**	**2.46**	**2.45**		**2.76**	**2.62**	

Notes:
1. Estimated Average Daily Cycle Times are based on field oversight.
2. Average Daily Cycle Time calculated using cycle times obtained from ClamVision© data. Jay Cashman, Inc daily activity summary and daily movement logs were used to remove ClamVision© data that corresponded to non-dredge times.
3. Average Daily Cycle Time calculated using cycle times greater than 0.75 minutes and less than 5.5 minutes. Ranges selected based on Jay Cashman , Inc video logs and typical environmental dredging cycles. Cycle times were obtained using ClamVision© data.
4. Range of Typical Cycle Time calculated using approximately 90 percent of data greater than 0.75 minutes and less than 5.5 minutes.
N/A= not applicable

Table 5-4: Sediment Volume Filled from December 2005 to April 2006

Bathymetric Surface 1	Bathymetric Surface 2	Dredge Cell	Cut (cubic yards)	Fill (cubic yards)	Net Fill (cubic yards)
December 11, 2005	February 15, 2006	11	2	570	570
December 11, 2005	February 15, 2006	13	2	300	300
December 11, 2005	February 15, 2006	15	4	580	580
Net Fill from December to February					**1,400**
February 15, 2006	April 18, 2006	11	0	390	390
February 15, 2006	April 18, 2006	13	0	200	200
February 15, 2006	April 18, 2006	15	1	340	330
Net Fill from February to April					**990**
December 11, 2005	April 18, 2006	11	2	960	960
December 11, 2005	April 18, 2006	13	2	500	500
December 11, 2005	April 18, 2006	15	5	920	910
Net Fill from December to April					**2,400**

Table 5-5: Estimated Volume of Dredged Material

Date	Calculated Daily Volume Dredged (cubic yards)	Reported Daily Volume Dredged by Jay Cashman, Inc.
December 5, 2005	886 ± 24	942
December 6, 2005	1,215 ± 31	1,366
December 7, 2005	772 ± 16	834
December 8, 2005	487 ± 10	486
December 10, 2005	628 ± 15	522
Total	**4,000 ±200**	**4,150**

Table 5-6: Daily Productivity Rates for the Pilot Study

	Maximum Operating Production Rate (cy/hr)	Average Operating Production Rate (cy/hr)	Site-Specific Operating Production Rate (cy/hr)
December 5, 2005	160	73	66
December 6, 2005	240	110	87
December 7, 2005	130	100	83
December 8, 2005	120	99	68
December 10, 2005	140	110	74
Average Rate for December 5 and December 6 Activity	**200**	**90**	**76**
Average Rate for December 7, 8, and 10 Activity when Best Management Practices were optimized	**130**	**100**	**76**

cy/hr= cubic yards/hour

Table 5-7A: Summary of Dredging Accuracy Data

(Considers All Bathymetric Data)

Design Cut Depth (feet below MLW)	Percent of Area Within 6 inches		Percent of Area Within 9 inches		Percent of Area Within 12 inches	
	Without Cable Arm Sensor	With Cable Arm Sensor	Without Cable Arm Sensor	With Cable Arm Sensor	Without Cable Arm Sensor	With Cable Arm Sensor
11 feet	60	69	74	81	84	90
13 feet	65	--	85	--	95	--
15 feet	--	79	--	90	--	95

Table 5-7B: Summary of Corrected Dredging Accuracy Data

(Corrected for Programming Error and the 3-foot Side Slope Between Design Cut)

Design Cut Depth (feet below MLW)	Corrected Percent of Area Within 6 inches		Corrected Percent of Area Within 9 inches		Corrected Percent of Area Within 12 inches	
	Without Cable Arm Sensor	With Cable Arm Sensor	Without Cable Arm Sensor	With Cable Arm Sensor	Without Cable Arm Sensor	With Cable Arm Sensor
11 feet	69	82	82	93	90	98
13 feet	66	--	87	--	97	--
15 feet	--	82	--	93	--	96

Notes:

MLW= mean low water

Table 6-1: Monitoring Instruments for Hydrodynamic Data

Mooring/Vessel	Instrument Location	Instrument Type	Measurements
Mooring 1	**Bottom**	**ADCP**	Velocities (cm/s) Reflectivity Pressure (depth m)
		OBS with CT sensor	Turbidity (NTU) Conductivity (S/m) Salinity (PSU) Temperature (° C/F)
	Top	**OBS w DL**	Turbidity (NTU)
		CTD	Conductivity (S/m) Salinity (PSU) Temperature (° C/F)
Mooring 2 & Mooring 5 & Mooring 6	**Bottom**	**ADCP**	Velocities (cm/s) Reflectivity Pressure (depth m)
		OBS	Turbidity (NTU)
		CTD	Conductivity (S/m) Salinity (PSU) Temperature (° C/F)
	Top	**OBS w DL**	Turbidity (NTU)
		CTD	Conductivity (S/m) Salinity (PSU) Temperature (° C/F)
Mooring 3 & Mooring 4	**Bottom**	**ADCP***	Velocities (cm/s) Reflectivity Pressure (depth m)
		OBS	Turbidity (NTU)
		CTD	Conductivity (S/m) Salinity (PSU) Temperature (° C/F)
	Top	**LISST**	Volume Concentrations (ul/l) Pressure (depth m) Temperature (° C/F)
		CTD**	Conductivity (S/m) Salinity (PSU) Temperature (° C/F)
R/V Caleta	**Variable**	**ADCP**	Velocities (cm/s)
		CTD	Conductivity (S/m) Salinity (PSU) Temperature (° C/F)
		OBS	Turbidity (NTU)
R/V Julia Miller	**Variable**	**LISST**	Volume Concentrations (ul/l) Pressure (depth m) Temperature (° C/F)
		CTD	Conductivity (S/m) Salinity (PSU) Temperature (° C/F)
		OBS	Turbidity (NTU)

Notes:
1. Mooring ADCP velocities are along channel, cross-channel, and vertical, and are based on principal axis determined by water flow direction.
2. *R/V Caleta* ADCP velocities are east-west and north-south and based on an absolute coordinate system.
* ADCP on Mooring 3 was a faulty instrument
**CTD on Mooring 4 was a faulty instrument

ADCP= Acoustic Doppler Current Profiling
Bottom= meter above bottom (mab)
cm/s= centimeter per second
CTD= Conductivity, Temperature, Depth
LISST= Laser In-Situ Scattering and Transmissometry
m= meter
NTU= Nephelometric Turbidity Units
OBS= Optical Backscatter Sensor
PSU= Practical Salinity Units
s/m= second per meter
Top = meter below surface (mbs)
ul/l= microliter per liter
°C/°F= Degrees Celsius or Fahrenheit

Table 6-2: Monitoring Instruments and Recording Frequency

Instrument and Location	Instrument Identification	Number of Records	Recording Frequency
ADCP-CTD-OBS Mooring 1	**C137**	**530**	Every 30 minutes
ADCP Mooring 2	**2484**	**15,684**	Every minute
ADCP Mooring 4	**5282**	**522**	Every 30 minutes
ADCP Mooring 5	**0375**	**522**	Every 30 minutes
ADCP Mooring 6	**3583**	**15,684**	Every minute
R/V Caleta ADCP		**17,566**	Approx. every 8 seconds
R/V Caleta CTD-OBS		**307**	Approx. every 3 minutes or longer
CTD-Mooring 1-surface	**3787**	**3510**	Every 5 minutes
CTD-Mooring 2-surface	**2615**	**3510**	Every 5 minutes
CTD-Mooring 3-surface	**3788**	**3510**	Every 5 minutes
CTD-Mooring 4-surface	**3790**	**3510**	Every 5 minutes
CTD-Mooring 5-surface	**2791**	**3512**	Every 5 minutes
CTD-Mooring 6-surface	**2682**	**3513**	Every 5 minutes
CTD-OBS-Mooring 2 bottom	**4170**	**3508**	Every 5 minutes
CTD-OBS-Mooring 3 bottom	**4169**	**3505**	Every 5 minutes
CTD-OBS-Mooring 5 bottom	**4168**	**3505**	Every 5 minutes
CTD-OBS-Mooring 6 bottom	**4583**	**3507**	Every 5 minutes
R/V Julia Miller CTD-OBS		**355**	Approx. every 2 minutes or longer
R/V Julia Miller LISST	**1051**	**24,528**	Every second
Mooring 3 surface LISST	**1054**	**592**	Every 30 minutes
Mooring 4 surface LISST	**1053**	**591**	Every 30 minutes
OBS-Mooring 1-surface	**2573**	**3249**	Every 5 minutes
OBS-Mooring 2-surface	**2570**	**3662**	Every 5 minutes
OBS-Mooring 5-surface	**2572**	**3490**	Every 5 minutes
OBS-Mooring 6-surface	2574	3489	Every 5 minutes

Notes:

ADCP= Acoustic Doppler Current Profiling

CTD= Conductivity-Temperature-Depth

LISST= Laser In-Situ Scattering and Transmissometery

OBS= Optical Backscatter Sensor

TSS= Total suspended solids

Table 6-3: Aqueous Volumes and Sediment Masses for TOPS Samples

Sample Identification	Date/Time	Volume of Water Filtered (Liters)	Calculated Mass of Sediment on Filters (grams)	Volume of Water Passed through XAD columns (Liters)
TD-GFF-051201-1130	**December 1, 2005 AM**	**261.3**	**18.8**	19.2
TU-GFF-051201-1130	**December 1, 2005 AM**	**225.5**	**16.8**	16.9
TD-GFF-051205-0730	**December 5, 2005 AM**	**154.9**	**3.83**	10.5
TU-GFF-051205-0730	**December 5, 2005 AM**	**231.8**	**5.19**	22.8
TD-GFF-051205-1430	**December 5, 2005 PM**	**143.2**	**7.92**	10.2
TU-GFF-051205-1430	**December 5, 2005 PM**	**148.3**	**6.07**	19.0
TD-GFF-051206-0830	**December 6, 2005 AM**	**346.6**	**6.11**	22.7
TU-GFF-051206-0830	**December 6, 2005 AM**	**305.4**	**7.54**	26.9
TD-GFF-051206-1430	**December 6, 2005 PM**	**235.5**	**8.95**	19.5
TU-GFF-051206-1430	**December 6, 2005 PM**	**251.3**	**9.03**	16.9
TD-GFF-051207-0930	**December 7, 2005 AM**	**408.3**	**6.33**	26.8
TU-GFF-051207-0930	**December 7, 2005 AM**	**195.2**	**3.44**	18.7
TD-GFF-051208-1030	**December 8, 2005 AM**	**295.3**	**8.46**	25.3
TU-GFF-051208-1030	**December 8, 2005 AM**	**221.7**	**9.07**	25.9
TD-GFF-051210-0730	**December 10, 2005 AM**	**323.8**	**10.1**	20.0
TU-GFF-051210-0730	**December 10, 2005 AM**	**209.1**	**9.29**	19.3
TD-GFF-051210-1230	**December 10, 2005 PM**	**158.0**	**5.48**	10.5

Sample Identification	**Date/Time**	**Volume of Water Filtered (Liters)**	**Calculated Mass of Sediment on Filters (grams)**	**Volume of Water Passed through XAD columns (Liters)**
TU-GFF-051210-1230	**December 10, 2005 PM**	**109.3**	**9.92**	14.0
TD-GFF-051212-0900*	**December 12, 2005 AM**	**309.1**	**8.62**	33.2

Notes:
1. Sample was mis-labeled as TD; should have been TU
GFF= Glass Fiber Filter
TD= TOPS Downriver
TU= TOPS Upriver
XAD= XAD-2 polystyrene exchange resin

Table 6-4: Analyte-Specific Detection Limits for Organic Compounds in TOPS Samples

Analyte	Minimum	Maximum	Average	Units
PCB Congeners – Dissolved	**0.01**	**1.00**	**0.11**	pg/L
PCB Congeners – Suspended	**0.01**	**132**	**4.19**	ng/kg
PCDD/F – Suspended	**0.06**	**18.2**	**1.76**	ng/kg
Pesticides – Suspended	**0.0001**	**0.82**	**0.086**	µg/kg
Total DDT – Suspended	**0.026**	**0.77**	**0.17**	µg/kg
Total Toxaphene – Suspended	**38**	**197**	**116**	µg/kg

Notes:

1. Total of all pesticides analyzed except for Toxaphene

ng/kg= nanograms per kilogram

pg/L= picograms per liter

µg/kg= micrograms per kilogram

Table 7-1: Median Particle Size for LISST Bins

LISST Bin Number (Size Class)	Median Particle Size (microns)
1	2.73
2	3.22
3	3.80
4	4.48
5	5.29
6	6.24
7	7.36
8	8.69
9	10.2
10	12.1
11	14.3
12	16.8
13	19.9
14	23.5
15	27.7
16	32.7
17	38.5
18	45.5
19	53.7
20	63.3
21	74.7
22	88.2
23	104
24	128
25	157
26	186
27	219
28	259
29	293
30	332
31	391
32	462

Notes:

1. Larger particle sizes identified in the higher bins represent flocculated particles rather than larger grain size particles (*i.e.*, sands).

Table 7-2: Sample Collection Summary

Analytical Parameter	Method	Matrix	Lab	Sample Number [5]	Analytes/ Sample	Data Points	Number Rejected	Percent Useable	Field Dupulicate	Table Identification[8]
Total Suspended Solids	160.2	Whole water	DESA	380	1	380	1 [7]	99.7%	28	14
Bromide/Chloride	C-67 [10]	Water	DESA	219	2	438	0	100%	7	14
Organic Carbon - Particulate (POC)	C-88 [9]	Filters [1]	DESA	231	1	231	0	100%		DB
Organic Carbon - Dissolved (DOC)	C-88 [9]	Filtered Water	DESA	168	1	168	0	100%	7	14
Mercury - Total	1631E	Whole water	STL -OH	18	1	18	N/A	100%	2	1
Mercury - Dissolved Phase	1631E	Filtered Water	STL -OH	8	1	8	N/A	100%	1	1
PCB Congeners - Suspended Phase	1668A	GFF (TOPS)	CLP[11]	19	159 [3b]	3021	0	100%	0	5
PCB Congeners - Dissolved Phase	1668A	XAD (TOPS)	CLP[11]	9	159 [3b]	1422 [3a]	0	100%	0	13
PCDD/F - Suspended Phase	1613B	GFF (TOPS)	CLP[11]	18 [6]	17	306	0	100%	0	6
PCDD/F - Dissolved Phase	1613B	XAD (TOPS)	CLP[11]	9	17	153	0	100%	0	10
Pesticides [4] - Suspended Phase	Lab SOP	GFF (TOPS)	CLP[11]	19	28	532	0	100%	0	3
Pesticides [4] - Dissolved Phase	Lab SOP	XAD (TOPS)	CLP[11]	9	28	252	0	100%	0	11
TAL Metals [2] - Total	ICP-MS	Whole water	DESA	16	19	304	0	100%	2	1
TAL Metals [2] - Dissolved Phase	ICP-MS	Filtered Water	DESA	10	19	190	0	100%	1	1

Notes:

1. Analysis conducted by DESA on filters prepared by USGS (Trenton).
2. Modified TAL suite.

3a. Number of PCB congener analytes is the list of individual congener results reported; coeluting congeners counted only once. Does not included derived quantities (*e.g.*, homolog sums or Total PCB).

3b. PCB-1 and PCB-2 not reported in four XAD samples; PCB-3 not reported in one sample. Value shown is number of data points reported by lab.

4. Pesticides were analyzed in three separate analyses and reported together; value is total of all three.
5. Sample quantity is environmental samples only; field duplicates, blanks, and other quality control samples (if any) not included.
6. Laboratory unable to report results for one GFF sample sumbitted for PCDD/F analysis due to quality control problems.
7. One anomalous data point determined to be unusable by Quality Assurance Officer.
8. References the Appendix J table number on which the data appear. "DB" indicates data are in the database but not on table in this report.
9. C-88 is the DESA laboratory SOP number for the organic carbon analysis (combustion/infrared method).
10. C-67 is the DESA laboratory SOP for bromide/chloride (based on USEPA method 300, ion chromatography).
11. Axys Analytical Services, the assigned USEPA Contract Laboratory Program (CLP) laboratory.

DESA= Division of Environmental Science and Assessment
GFF= Glass Fiber Filters
PCB= Polychlorinated Biphenyl
PCDD/F= Polychlorinated Dibenzodioxin/Furan
SOP= Standard Operating Procedures
STL-OH= Severn Trent Laboratories in Knoxville, Tenessee
TAL= Target Analyte List
TOPS= Trace Organic Platform Sampler
USEPA= United States Environmental Protection Agency
USGS= United States Geologic Survey
XAD= XAD-2 polystyrene exchange resin

Table 7-3: Organics Data Sample Analysis Overview

Organic Samples	PCDD/F E1613B	PCB Congeners MLA-013 Rev 5	Pesticides: Pesticide Fraction #1 (18 target analytes)	Pesticides: Pesticide Fraction #2 (9 target analytes)	Pesticides: Toxaphene
TD-GFF-051201-1130	L8514-1 RX + Dil5	L8514-1	L8514-1 RX MLA 07	18514-1 Li; MLA 13	L8514-1 RX M MLA 07
TD-GFF-051205-0730	L8514-2	L8514-2	L8514-2 RX MLA 07	18514-2; MLA 13	L8514-2 RX M MLA 07
TD-GFF-051205-1430	L8514-3 RX + Dil5	L8514-3	L8514-3 RX MLA 07	18514-3 Li; MLA 13	L8514-3 RX M MLA 07
TD-GFF-051206-0830	L8514-4	L8514-4	L8514-4 RX MLA 07	18514-4; MLA 13	L8514-4 RX M MLA 07
TD-GFF-051206-1330	L8514-5 RX + Dil5	L8514-5	L8514-5 RX MLA 07	18514-5 Li; MLA 13	L8514-5 RX M MLA 07
TD-GFF-051207-0930	L8514-6 RX	L8514-6	L8514-6 RX MLA 07	18514-6 Li; MLA 13	L8514-6 RX M MLA 07
TD-GFF-051208-1030	L8514-7 RX W (Dil5)	L8514-7	L8514-7 RX MLA 07	18514-7 Li; MLA 13	L8514-7 RX M MLA 07
TD-GFF-051210-0730	L8514-8 RX W (Dil5)	L8514-8	L8514-8 RX MLA 07	18514-8 Li; MLA 13	L8514-8 RX M MLA 07
TD-GFF-051210-1230	L8514-9 RX W (Dil5)	L8514-9	L8514-9 RX MLA 07	18514-9 W; MLA 13	L8514-9 RX M MLA 07
TD-GFF-051212-0730	L8514-10	L8514-10	L8514-10 RX MLA 07	18514-10; MLA 13	L8514-10 RX M MLA 07
TD-GFF-051212-0900	L8514-11 RX W (Dil5)	L8514-11 M	L8514-11 L3i MLA 13	L8514-11RX i MLA 07	L8514-11 L; MLA 13
TD-XAD-051201-1130	L8518-1	L8518-1	L8518-1 i; MLA 07	L8518-1 i4 MLA 07	L8518-1 MLA 13
TD-XAD-051205-1430	L8518-3	L8518-3	L8518-3 i; MLA 07	L8518-3 i4 MLA 07	L8518-3 MLA 13
TD-XAD-051206-1330	L8518-5	L8518-5	L8518-5 i; MLA 07	L8518-5 i3 MLA 07	L8518-5 MLA 13
TD-XAD-051210-0730	L8518-8	L8518-8	L8518-8 i; MLA 07	L8518-8 i3 MLA 07	L8518-8 MLA 13
TD-XAD-051212-0730	L8518-10	L8518-10	L8518-10 i; MLA 07	L8518-10 i4 MLA 07	L8518-10 MLA 13
TD-XAD-051212-0900	L8518-11	L8518-11	L8518-11 i; MLA 07	L8518-11 i4 MLA 07	L8518-11 MLA 13
TU-GFF-051201-1130	Interference; no usable data	L8514-12 M	L8514-12 L3i2 MLA 13	L8514-12RX i MLA 07	L8514-12 L; MLA 13
TU-GFF-051205-0730	L8514-13 L	L8514-13 i	L8514-13 L3i2 MLA 13	L8514-13RX i MLA 07	L8514-13 L; MLA 13
TU-GFF-051205-1430	L8514-14 RX W (Dil5)	L8514-14 i	L8514-14 L3i MLA 13	L8514-14RX i2 MLA 07	L8514-14 L; MLA 13
TU-GFF-051206-0830	L8514-15 RX W (Dil5)	L8514-15 i	L8514-15 L3i2 MLA 13	L8514-15RX i2 MLA 07	L8514-15 L; MLA 13
TU-GFF-051206-1330	L8514-16 RX W (Dil5)	L8514-16 i	L8514-16 L3i MLA 13	L8514-16RX i2 MLA 07	L8514-16 L2; MLA 13
TU-GFF-051207-0930	L8514-17 L	L8514-17 i	L8514-17 L3i MLA 13	L8514-17RX i2 MLA 07	L8514-17 L; MLA 13
TU-GFF-051208-1030	L8514-18 L / LW	L8514-18 i	L8514-18 L3i2 MLA 13	L8514-18RX i2 MLA 07	L8514-18 L2; MLA 13
TU-GFF-051210-0730	L8514-19 RX W (Dil5)	L8514-19	L8514-19 L3i MLA 13	L8514-19RX i2 MLA 07	L8514-19 L2i; MLA 13
TU-GFF-051210-1230	L8514-20 RX W (Dil5)	L8514-20	L8514-20 L3i MLA 13	L8514-20RX i2 MLA 07	L8514-20 L2; MLA 13
TU-XAD-051201-1130	L8518-12	L8518-12	L8518-12 i; MLA 07	L8518-12 i3 MLA 07	L8518-12 MLA 13
TU-XAD-051206-1330	L8518-16	L8518-16	L8518-16 i; MLA 07	L8518-16 i3 MLA 07	L8518-16 MLA 13
TU-XAD-051207-0930	L8518-17	L8518-17	L8518-17 i; MLA 07	L8518-17 i2 MLA 07	L8518-17 MLA 13
TU-XAD-051208-1030	L8518-18	L8518-18	L8518-18 i; MLA 07	L8518-18 i2 MLA 07	L8518-18 MLA 13
Total	29 of 30	30 of 30	30 of 30	30 of 30	30 of 30

Notes

1. Numbers are the CLP sample number as shown on the electronic deliverable for the cited analysis (Axys Analytical Services is the assigned USEPA CLP laboratory).
2. Multiple methods (MLA 07 and MLA 13) reported for pesticides.
3. Pesticide Fraction #1 (18 target analytes) is a suite of 18 pesticide compounds. This fraction does not overlap with the Pesticide Fraction #2 (9 target analytes) that are reported separately. Toxaphene is not included in Pesticide Fraction #1 (18 target analytes) or Pesticide Fraction #2 (9 target analytes).
4. All glass fiber filter PCB congeners included individual peaks reported at 10 times the dilution factor.
5. Most PCDD/F parameters (except 2,3,7,8-TCDD) reported at 5 times the dilution factor.
6. Blanks cells indicate that no data were located for that parameter in that sample.
7. XAD Pesticides Suite 1 has only 15 to 17 (out of 18) pesticides reported.

Table 8-1: Suspended Sediment Flux under Maximum Ebb and Maximum Flood Conditions

	Average Sediment Flux (kg/s)	**Total Sediment Mass (kg)**	**Maximum Sediment Flux (kg/s)**	**Percent Δ Sediment Flux** (Transect A->F)	**Average Flow Rate (m^3/s)**	**Total Water Volume (m^3)**	**Percent Δ Water Flow** (Transect A->F)
Maximum Ebb Conditions							
December 3, 2005							
Transect A – Mooring 1 and 2 (Figure 8-2)	35	381,000	49.8	-2%	448	4,835,000	-8%
Transect F – Mooring 5 and 6 (Figure 8-2)	34	371,000	44.7		411	4,433,000	
December 5, 2005							
Transect A – Mooring 1 and 2 (Figure 8-4)	13	137,000	16.1	11%	228	2,468,000	4%
Transect F – Mooring 5 and 6 (Figure 8-4)	14	153,000	16.6		239	2,576,000	
December 6, 2005							
Transect A – Mooring 1 and 2 (Figure 8-5)	12	128,000	13.2	12%	223	2,407,000	-10%
Transect F – Mooring 5 and 6 (Figure 8-5)	13	144,000	16.6		202	2,177,000	
Maximum Flood Conditions							
	Average Sediment Flux (kg/s)	**Total Sediment Mass (kg)**	**Maximum Sediment Flux (kg/s)**	**Percent Δ Sediment Flux** (Transect F->A)	**Average Flow Rate (m^3/s)**	**Total Water Volume (m^3)**	**Percent Δ Water Flow** (Transect F->A)
December 3, 2005							
Transect A – Mooring 1 and 2 (Figure 8-3)	-6.7	-72,800	-12.2	-16%	-124	-1,338,000	-11%
Transect F – Mooring 5 and 6 (Figure 8-3)	-8.0	-86,500	-15.6		-140	-1,509,000	
December 7, 2005							
Transect A – Mooring 1 and 2 (Figure 8-6)	-2.2	-24,300	-3.2	0%	-105	-1,133,000	-1%
Transect F – Mooring 5 and 6 (Figure 8-6)	-2.2	-24,300	-3.3		-106	-1,141,000	
December 8, 2005*							
Transect A – Mooring 1 and 2 (Figure 8-7)	-6.4	-57,600	-8.7	-13%	-204	-1,837,000	7%
Transect F – Mooring 5 and 6 (Figure 8-7)	-7.4	-66,300	-11.9		-192	-1,724,000	

Notes:
1. Data for December 8, 2005 is over a 2.5 hour time period in comparison to the 3 hour time periods used for December 5-7, 2005.
2. Refer to Figure 5-4 for positioning of transects.

kg= kilogram
kg/s= kilograms per second
m^3= cubic meter
m^3/s= cubic meters per second

Table 8-2: Net Suspended Sediment Flux from the Pair-Wise Analysis Summary

During Dredging

Date	Ebb		Flood		Average Net Flux All Data Pairs (kg/s)
	Average Flux during Dredging (kg/s)	Number of Data Points	Average Flux during Dredging (kg/s)	Number of Data Points	
12/5/2005	2.3	6			2.3
12/6/2005	6.7	5	0.8	3	4.5
12/7/2005	0.59	2	0.59	6	0.59
12/8/2005			4.1	3	4.1
12/10/2005	-2.3	6	12	4	3.6
Mean	1.8	19	4.2	16	2.9
Median	1.3		1.1		1.1
Standard Error x 2	2.0		3.4		1.9

During Non-Dredging

Date	Ebb		Flood		Average Net Flux All Data Pairs (kg/s)
	Average Flux Non-Dredging (kg/s)	Number of Data Points	Average Flux Non-Dredging (kg/s)	Number of Data Points	
12/5/2005			-1.2	1	-1.2
12/6/2005			2.6	3	2.6
12/7/2005	1.7	2			1.7
12/8/2005	-1.6	2			-1.6
12/10/2005	-0.36	1	6.2	2	4.0
Mean	0.47	5	3.2	6	2.0
Median	0.043		1.7		0.28
Standard Error x 2	1.4		4.0		2.4

Notes:
kg/s = kilograms per second

Table 8-3: Net Suspended Sediment Flux Estimated by Plume-Width and Cross Section Methods from *R/V Caleta*

Date	Military Time	Method Used	Net Solids Flux (kg/s)
December 5, 2005	11:19	Plume Width Basis	-0.14
December 5, 2005	12:18	Plume Width Basis	-0.01
December 5, 2005	12:42	Cross-section Basis	2.40
December 5, 2005	12:57	Cross-section Basis	0.42
December 5, 2005	13:00	Plume Width Basis	0.07
December 5, 2005	13:46	Plume Width Basis	1.31
December 5, 2005 *	13:47	Plume Width Basis	0.90
December 5, 2005 *	14:25	Plume Width Basis	2.00
December 5, 2005	15:21	Cross-section Basis	2.45
December 5, 2005	16:22	Cross-section Basis	1.23
December 6, 2005	9:59	Plume Width Basis	-0.23
December 6, 2005	13:17	Plume Width Basis	0.26
December 6, 2005 *	14:02	Plume Width Basis	4.30
December 6, 2005 *	14:51	Plume Width Basis	1.80
December 6, 2005	14:55	Cross-section Basis	2.93
December 6, 2005	14:53	Plume Width Basis	1.43
December 6, 2005	15:36	Plume Width Basis	0.95
December 6, 2005	15:36	Cross-section Basis	1.58
December 7, 2005	9:18	Plume Width Basis	-0.01
December 7, 2005	9:28	Cross-section Basis	-0.43
December 7, 2005	9:46	Plume Width Basis	0.42
December 7, 2005	9:57	Cross-section Basis	-0.58
December 7, 2005	11:03	Plume Width Basis	0.34
December 7, 2005	11:38	Plume Width Basis	0.16
December 7, 2005	13:04	Plume Width Basis	0.11
December 7, 2005	13:40	Plume Width Basis	0.03
December 7, 2005	14:50	Plume Width Basis	0.68
December 7, 2005	15:04	Plume Width Basis	0.81
December 7, 2005	16:01	Plume Width Basis	0.70
December 7, 2005	16:02	Cross-section Basis	0.87
December 7, 2005 *	16:10	Plume Width Basis	1.50
December 8, 2005	10:05	Plume Width Basis	0.77
December 8, 2005	10:16	Cross-section Basis	-1.28
December 8, 2005 *	11:41	Plume Width Basis	1.00
December 8, 2005	12:13	Cross-section Basis	0.61
December 8, 2005	12:14	Cross-section Basis	0.93
December 8, 2005	12:54	Plume Width Basis	0.10
December 8, 2005	14:44	Plume Width Basis	0.15
December 10, 2005	8:52	Plume Width Basis	-0.32
December 10, 2005	9:34	Plume Width Basis	-0.23
December 10, 2005	8:53	Cross-section Basis	0.15
December 10, 2005	8:54	Cross-section Basis	0.22
December 10, 2005	9:07	Cross-section Basis	-0.06
December 10, 2005	9:34	Cross-section Basis	0.26
December 10, 2005 *	12:47	Plume Width Basis	2.10
December 10, 2005	12:57	Cross-section Basis	0.22
December 10, 2005 *	13:38	Plume Width Basis	2.70
December 10, 2005	13:58	Cross-section Basis	1.04

Notes:
* Surveys with observed plume (refer to Appendix G)
kg/s= kilograms per second

Table 8-4: Resuspension Rates in the Very-Near Field

Date	Volume Dredged (cy)	Dredging Time (hr)	Production Rate (cy/hr)	Cycle Time (min)	CY per Cycle	Production Rate (kg/s)	Average Net Suspended Sediment Flux (kg/s)	Very Near-Field Percent Resuspension
December 5, 2005	886	5.4	164	2.11	5.8	19.3	1.06	5.52
December 6, 2005	1,215	5.0	243	2.01	8.1	28.5	1.63	5.70
December 7, 2005	772	5.8	133	2.73	6.1	15.6	0.35	2.26
December 8, 2005	487	4.0	122	2.89	5.9	14.3	0.32	2.27
December 9, 2005	No dredging due to weather							
December 10, 2005	628	4.6	137	2.57	5.8	14.3	0.61	4.25

Notes:

1. Volume dredged taken from Dredging Contractor Final Completion Report (Appendix A). The volumes are based on daily bathymetric surveys.
2. Actual Dredging time (no standby, downtime, or equipment movement)
3. Production rate (cy/hr) = volume dredged (cy) / dredging time (hr)
4. Cycle time was determined from video logs and clamvision data (see Table 5-3)
5. Cubic yards per cycle time = production rate (cy/hr) * cycle time (min) / (60 min/hr)
6. Production rate (kg/s) = production rate (cy/hr) / (60 min/hr) / (60 s/min) * 0.76455 (m^3/cy) * dry bulk density (kg/m^3)
7. Average net suspended sediment flux in kg/s by date
8. Very near-field percent resuspension = average net suspended sediment flux (kg/s) / production rate (kg/s) * 100%

cy= cubic yard
cy/hr= cubic yards per hour
kg/m^3= kilograms per cubic meter
kg/s= kilograms per second
m^3/cy= cubic meters per cubic yard
min= minute
min/hr= minutes per hour
s/min= seconds per minute

Table 8-5: Comparison of TOPS Boat Sample Data

Sample Identification		TU-051201-1130-I	TD-051201-1130-I	TU-051205-0730-I	TD-051205-0730-I	TU-051205-1430-I	TD-051205-1430-I	TU-051206-0830-I	TD-051206-0830-I	TU-051206-1330-I	TU-051206-1330-I-Dup	TD-051206-1330-I
Sample Location		Upriver	Downriver	Upriver	Downriver	Upriver	Downriver	Upriver	Downriver	Upriver	Upriver	Downriver
Sample Date		December 1, 2005	December 1, 2005	December 5, 2005	December 5, 2005	December 5, 2005	December 5, 2005	December 6, 2005	December 6, 2005	December 6, 2005	December 6, 2005	December 6, 2005
Planned Sample Time		1130	1130	0730	0730	1430	1430	0830	0830	1330	1330	1330
Approximate Sample Time		11:30-14:42	11:30-14:15	08:30-12:03	08:30-12:03	14:00-17:12	14:00-17:11	08:00-11:42	08:02-11:47	13:30-16:42	13:30-16:42	13:30-16:13
Tidal Cycle		Ebb	Ebb	Flood to Ebb	Flood to Ebb	Ebb	Ebb	Flood	Flood	Ebb	Ebb	Ebb
Analyte	**Units**											
Suspended Phase Organics/Unfiltered Metals												
2,3,7,8-TCDD	pg/L	NA	17 BD	6.2	3.5	40 D	27 D	8.3 D	4.1	10.0 D	NA	14 D
Total DDT	ng/L	11.8 D	16.6 EMPC	2.57	1.43	14.75 EMPC	6.03 EMPC	4.72	3.96 EMPC	2.36 T	NA	9.56 EMPC
Total PCB	pg/L	66,902	56,483	19,578	11,635	58,655	70,868	24,423	17,324	31,252	NA	52,759
Lead, Total	µg/L	21	17	NA	NA	15	18	9.5	5.1	8.0	12	29
Mercury, Total	ng/L	21	18	8.9	12	9.2	16	11	14	20	NA	NA
Dissolved Phase Organics and Metals												
2,3,7,8-TCDD	pg/L	0.19 JEMPC	0.21 JEMPC	NA	NA	NA	0.20 JEMPC	NA	NA	0.16 J	NA	0.14 JEMPC
Total DDT	ng/L	0.449 J	0.578 JEMPC	NA	NA	NA	0.411 JEMPC	NA	NA	0.404 J	NA	0.380 EMPC
Total PCB	pg/L	3,605	4,833	NA	NA	NA	3,745	NA	NA	2,988	NA	3,660
Lead, Dissolved	µg/L	0.85	NA	NA	NA	NA	0.89	NA	NA	0.79	0.73	0.97
Mercury, Dissolved	ng/L	NA	4.2	NA	NA	NA	NA	2.6	2.6	3.4	NA	NA

Sample Identification		TD-051206-1330-I-Dup	TU-051207-0930-I	TD-051207-0930-I	TU-051208-1030-I	TU-051208-1030-I-Dup	TD-051208-1030-I	TU-051210-0730-I	TD-051210-0730-I	TU-051210-1230-I	TD-051210-1230-I	TD-051212-0900-I
Sample Location		Downriver	Upriver	Downriver	Upriver	Upriver	Downriver	Upriver	Downriver	Upriver	Downriver	At Dredged Site
Sample Date		December 6, 2005	December 7, 2005	December 7, 2005	December 8, 2005	December 8, 2005	December 8, 2005	December 10, 2005	December 10, 2005	December 10, 2005	December 10, 2005	December 12, 2005
Planned Sample Time		1330	0930	0930	1030	1030	1030	0730	0730	1230	1230	0900
Approximate Sample Time		13:30-16:13	09:30-12:42	09:40-12:25	10:30-13:42	10:30-13:42	10:30-13:30	07:30-10:12	07:35-10:17	12:30-14:13	12:37-14:49	08:00-11:45
Tidal Cycle		Ebb	Flood	Flood	Flood	Flood	Flood	Ebb	Ebb	Flood	Flood	Ebb
Analyte	**Units**											
Suspended Phase Organics/Unfiltered Metals												
2,3,7,8-TCDD	pg/L	N/A	5.4	15	99 D	N/A	13 D	64 D	12 BD	32 D	12 D	6.7 D
Total DDT	ng/L	N/A	2.70	3.00 EMPC	3.24	N/A	5.66 EMPC	6.27	4.71 EMPC	18.3 EMPC	2.37	10.60
Total PCB	pg/L	N/A	16,623	17,208	29,097	N/A	35,513	48,893	33,363	105,154	37,793	23,413
Lead, Total	µg/L	1.9	5.7	4.1	12	N/A	6.7	18	12	32	13	7.7
Mercury, Total	ng/L	35	14	27	15	12	16	23	24	88	130	10
Dissolved Phase Organics and Metals												
2,3,7,8-TCDD	pg/L	N/A	0.16 JEMPC	N/A	0.12 JEMPC	N/A	N/A	N/A	0.16 J	N/A	N/A	0.11 JEMPC
Total DDT	ng/L	N/A	0.390	N/A	1.090 EMPC	N/A	N/A	N/A	0.440	N/A	N/A	0.339 J
Total PCB	pg/L	N/A	4,167	N/A	3,376	N/A	N/A	N/A	3,911	N/A	N/A	3,324
Lead, Dissolved	µg/L	N/A	0.52	0.61	0.50 U	N/A	0.54	N/A	0.60	N/A	N/A	0.83
Mercury, Dissolved	ng/L	N/A	2.5	2.7	1.6	1.5	NA	N/A	2.3	N/A	N/A	N/A

Notes:
1. Total DDT is the sum of detected values of 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT
B= Also detected in Blank
D= Value from Dilution Analysis
EMPC= Estimated Maximum Possible Concentration
J= Estimated Value
N/A= Not Analyzed
ng/L= nanograms per liter
pg/L= picograms per liter
µg/L= micrograms per liter

Table 8-6: Suspended Sediment Collected in TOPS Boat Samples

Sample Identification		TU-051201-1130-I	TD-051201-1130-I	TU-051205-0730-I	TD-051205-0730-I	TU-051205-1430-I	TD-051205-1430-I	TU-051206-0830-I	TD-051206-0830-I	TU-051206-1330-I	TU-051206-1330-I-Dup	TD-051206-1330-I
Sample Location		Upriver	Downriver	Upriver	Downriver	Upriver	Downriver	Upriver	Downriver	Upriver	Upriver	Downriver
Sample Date		December 1, 2005	December 1, 2005	December 5, 2005	December 5, 2005	December 5, 2005	December 5, 2005	December 6, 2005	December 6, 2005	December 6, 2005	December 6, 2005	December 6, 2005
Planned Sample Time		1130	1130	0730	0730	1430	1430	0830	0830	1330	1330	1330
Approximate Sample Time		11:30-14:42	11:30-14:15	08:30-12:03	08:30-12:03	14:00-17:12	14:00-17:11	08:00-11:42	08:02-11:47	13:30-16:42	13:30-16:42	13:30-16:13
Tidal Cycle		Ebb	Ebb	Flood to Ebb	Flood to Ebb	Ebb	Ebb	Flood	Flood	Ebb	Ebb	Ebb
Analyte	**Units**											
Suspended Sediment												
2,3,7,8-TCDD	pg/g	NA	232 BD	276	143	973 D	495 D	334 D	234	278 D	NA	371 D
Total DDT	ng/g	160.0	226.0 Q	113.0	57.8	358.0 Q	108.0 Q	192.0	223.5 Q	67.0 Q	NA	251.0 Q
Total PCB	pg/g	901,376	789,013	875,345	470,311	1,431,388	1,274,634	989,949	984,421	870,543	NA	1,385,630

Sample Identification		TD-051206-1330-I-Dup	TU-051207-0930-I	TD-051207-0930-I	TU-051208-1030-I	TU-051208-1030-I-Dup	TD-051208-1030-I	TU-051210-0730-I	TD-051210-0730-I	TU-051210-1230-I	TD-051210-1230-I	TD-051212-0900-I
Sample Location		Downriver	Upriver	Downriver	Upriver	Upriver	Downriver	Upriver	Downriver	Upriver	Downriver	At Dredged Site
Sample Date		December 6, 2005	December 7, 2005	December 7, 2005	December 8, 2005	December 8, 2005	December 8, 2005	December 10, 2005	December 10, 2005	December 10, 2005	December 10, 2005	December 12, 2005
Planned Sample Time		1330	0930	0930	1030	1030	1030	0730	0730	1230	1230	0900
Approximate Sample Time		13:30-16:13	09:30-12:42	09:40-12:25	10:30-13:42	10:30-13:42	10:30-13:30	07:30-10:12	07:35-10:17	12:30-14:13	12:37-14:49	08:00-11:45
Tidal Cycle		Ebb	Flood	Flood	Flood	Flood	Flood	Ebb	Ebb	Flood	Flood	Ebb
Analyte	**Units**											
Suspended Sediment												
2,3,7,8-TCDD	pg/g	NA	308	969 B	2,414 D	NA	459 D	1,432 D	385 D	351 D	343 D	240 D
Total DDT	ng/g	NA	151.0	193.0 Q	79.2	NA	196.0 Q	142.0	150.0 Q	201.0 Q	68.0	379.0
Total PCB	pg/g	NA	943,701	1,109,241	712,142	NA	1,241,394	1,098,247	1,068,547	1,159,394	1,090,084	840,281

Notes:
1. Total DDT is the sum of detected values of 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT
B= Also detected in Blank
D= Value from Dilution Analysis
Q= Estimated Maximum Possible Concentration
NA= Not Analyzed
ng/L= nanograms per liter
pg/L= picograms per liter

Table 8-7: Concentrations of Selected Organics in Dredge Prism

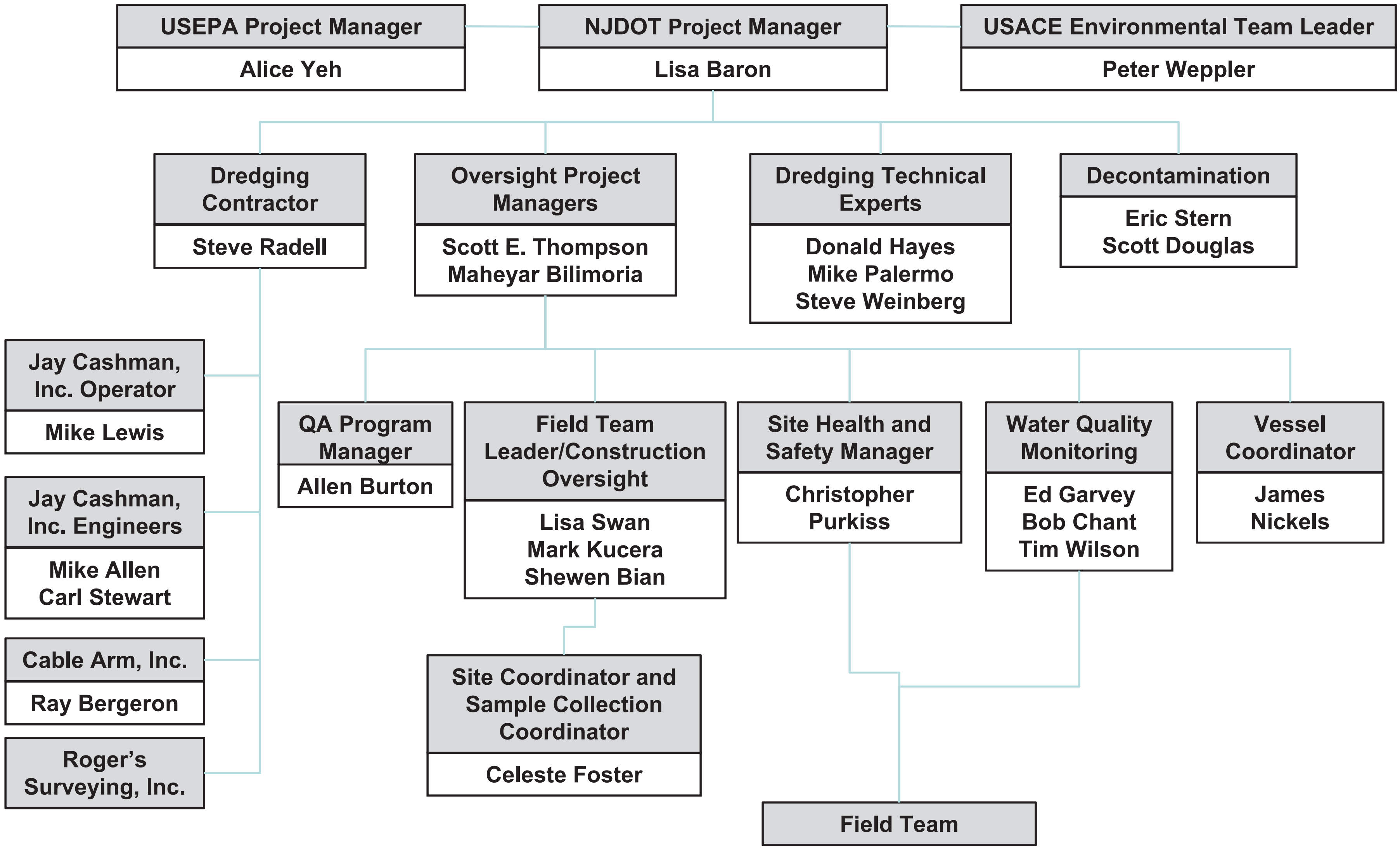
Cell Identification	2,3,7,8-TCDD ng/kg	Total DDT µg/kg	Total PCB µg/kg
A1	**490**	**60**	3,500
B1	**633**	**92**	4,188
C1	**363**	**92**	4,264
D1	**630**	**95**	4,465
E1	**1,067**	**117**	4,143
A2	**490**	**300**	3,500
B2	**633**	**64**	4,188
C2	**363**	**175**	4,264
D2	**630**	**117**	4,465
E2	**1,067**	**492**	4,143
A3	**490**	**86**	3,500
B3	**633**	**192**	4,188
C3	**363**	**187**	4,264
D3	**630**	**197**	4,465
E3	**1,067**	**88**	4,143

Notes:

1. TAMS/ET and Malcolm Pirnie, Inc. (2005b). Final Data Summary and Evaluation Report.

ng/kg= nanograms per kilogram

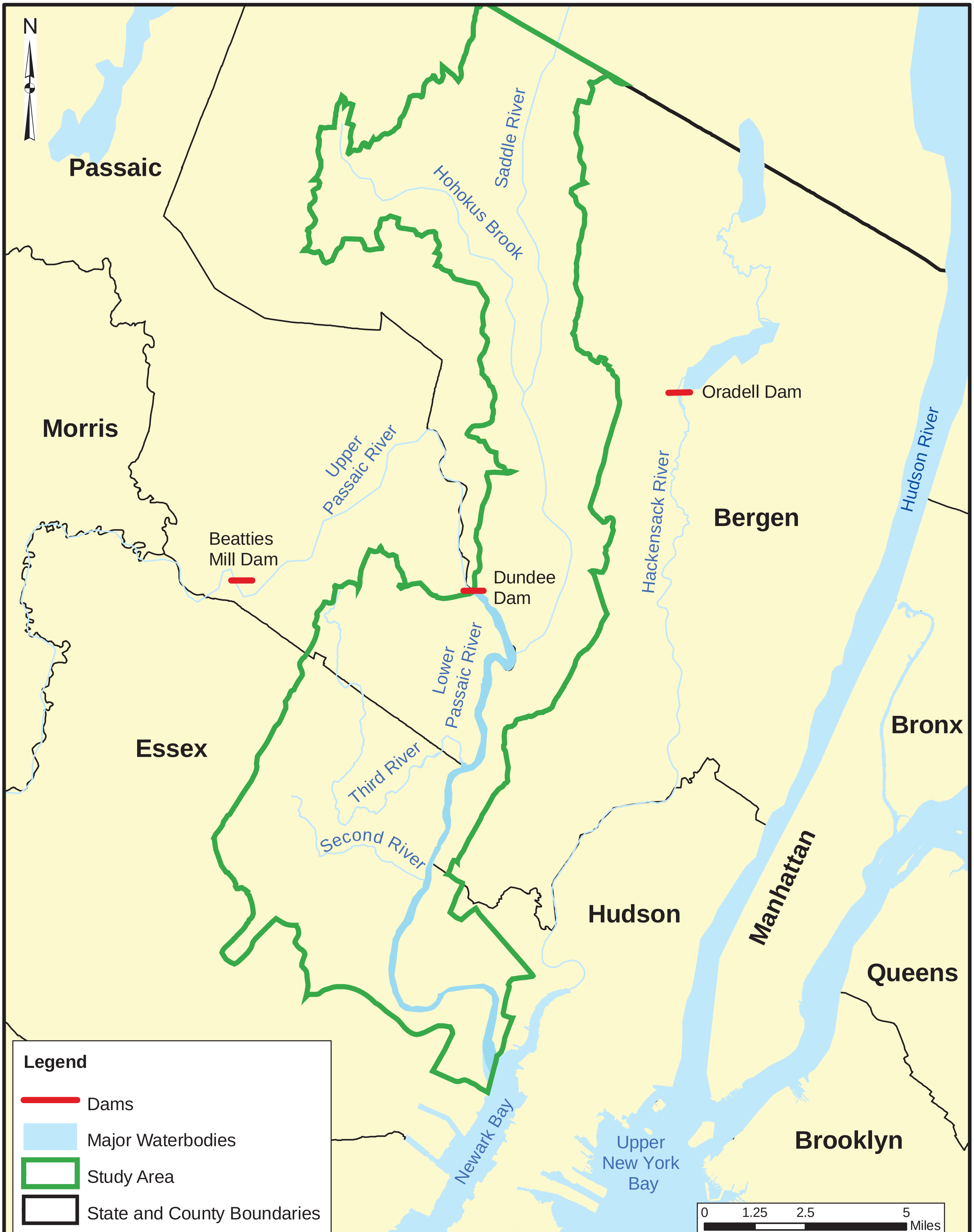
µg/kg= micrograms per kilogram



Project Organization Chart

Lower Passaic River Restoration Project

Figure 1-1



Lower Passaic River Restoration Project Map

Lower Passaic River Restoration Project

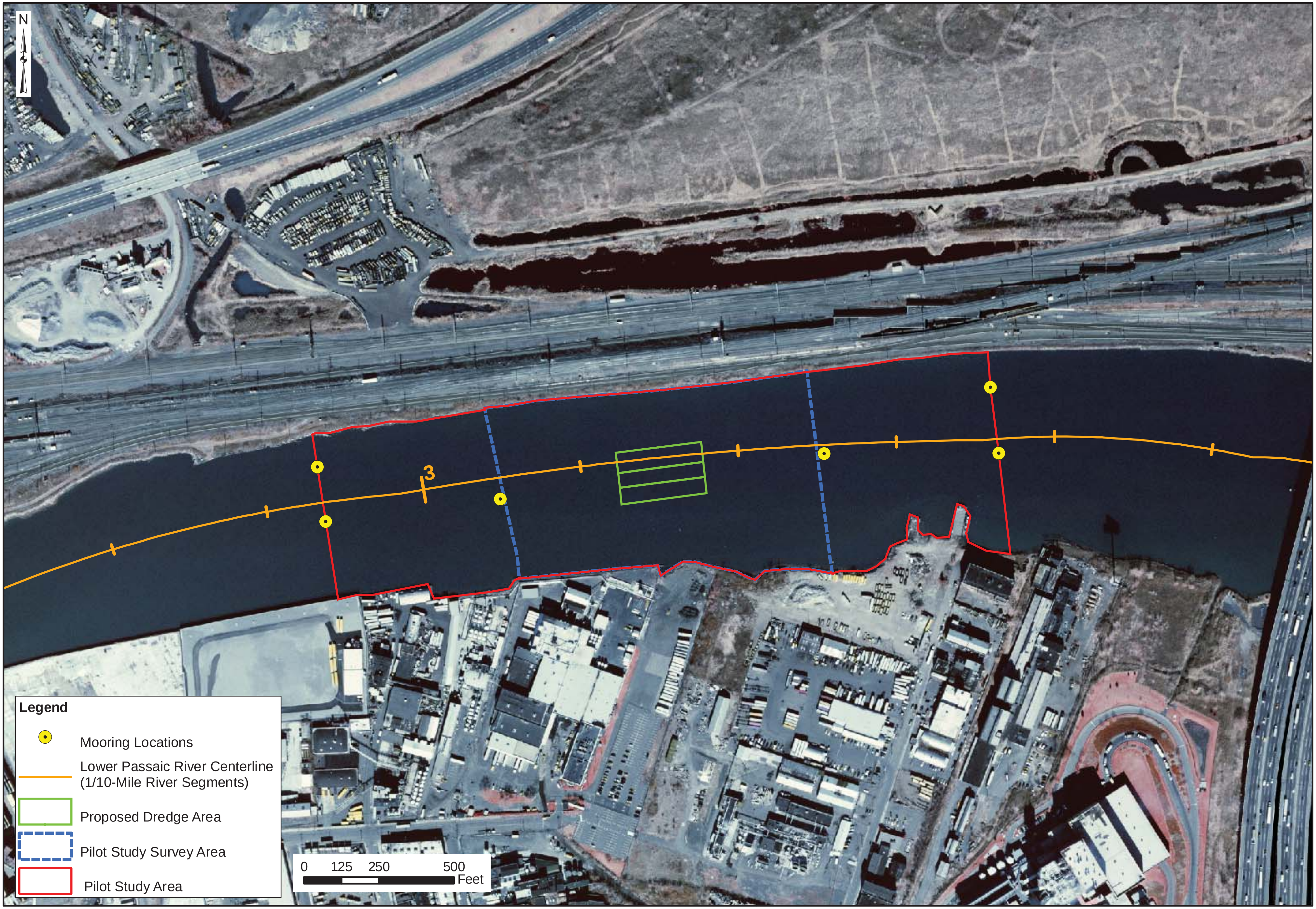
Figure 1-2

Pilot Study Area Location Map

Lower Passaic River Restoration Project

Data Source:
1) Aerials, NJGIN, 2002

Figure 3-1



Proposed Dredge and Survey Areas
Lower Passaic River Restoration Project

Data Source:
1) Aerials, NJGIN, 2002

Figure 3-2

S:\Projects\passaic\MapDocuments\4553001-CERCLA\DredgePilot_Survey_ProposedDredgeArea.mxd

Photograph of Bridges
(New Jersey Turnpike, RM 4.4; and Point-No-Point Conrail Bridges, RM 2.3)

Lower Passaic River Restoration Project

Figure 3-3a

Photographs of Bridges
(Jackson Street Bridge, RM 4.4)

Lower Passaic River Restoration Project

Figure 3-3b

Photographs of the Northern Shoreline Features

Lower Passaic River Restoration Project

Figure 3-4

Photographs of the Southern Shoreline Features

Lower Passaic River Restoration Project

Figure 3-5a

Photographs of the Southern Shoreline Features

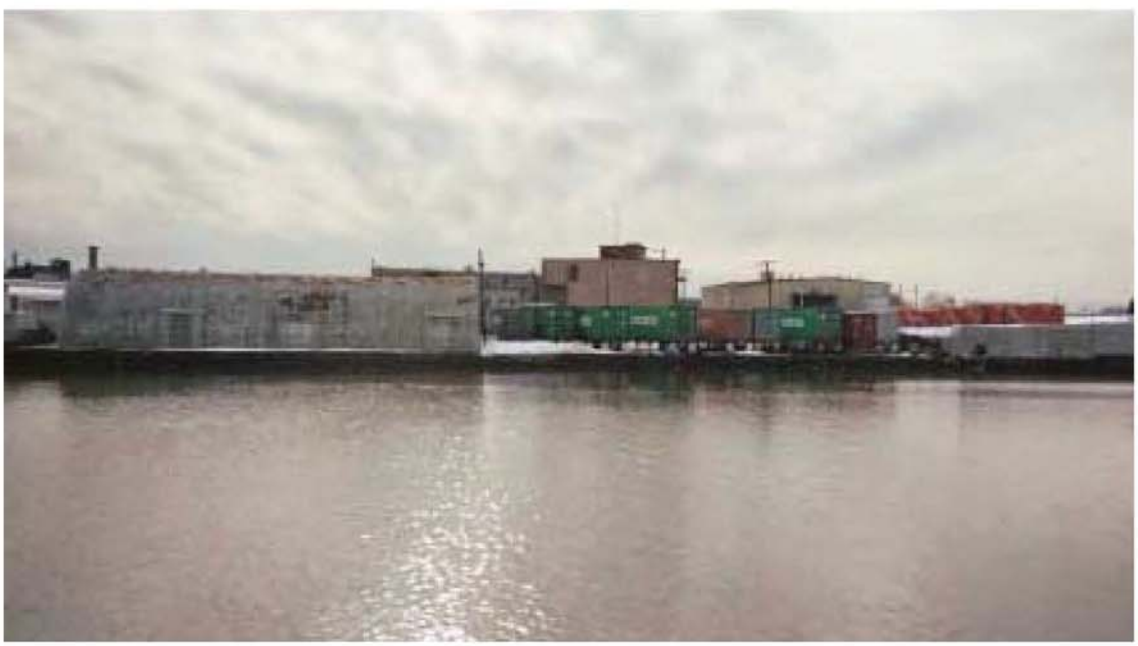
Lower Passaic River Restoration Project

Figure 3-5b

Photographs of the Southern Shoreline Features

Lower Passaic River Restoration Project

Figure 3-5c



Photographs of the Southern Shoreline Features

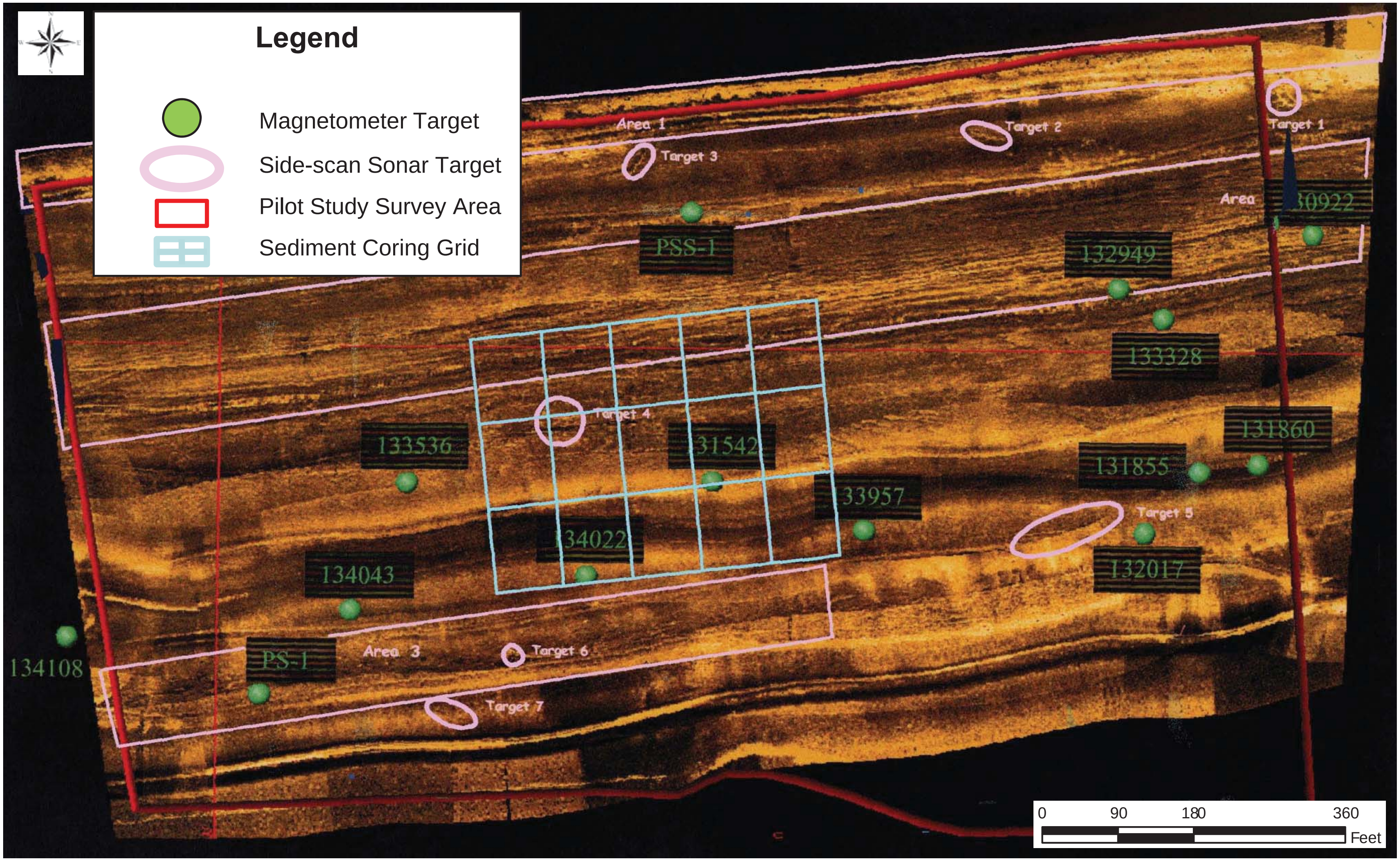
Lower Passaic River Restoration Project

Figure 3-5d

Photographs of the Southern Shoreline Features

Lower Passaic River Restoration Project

Figure 3-5e



Magnetic Anomalies and Sub-Bottom Profiler Targets Overlaid on Side-Scan Sonar Targets and Mosaic

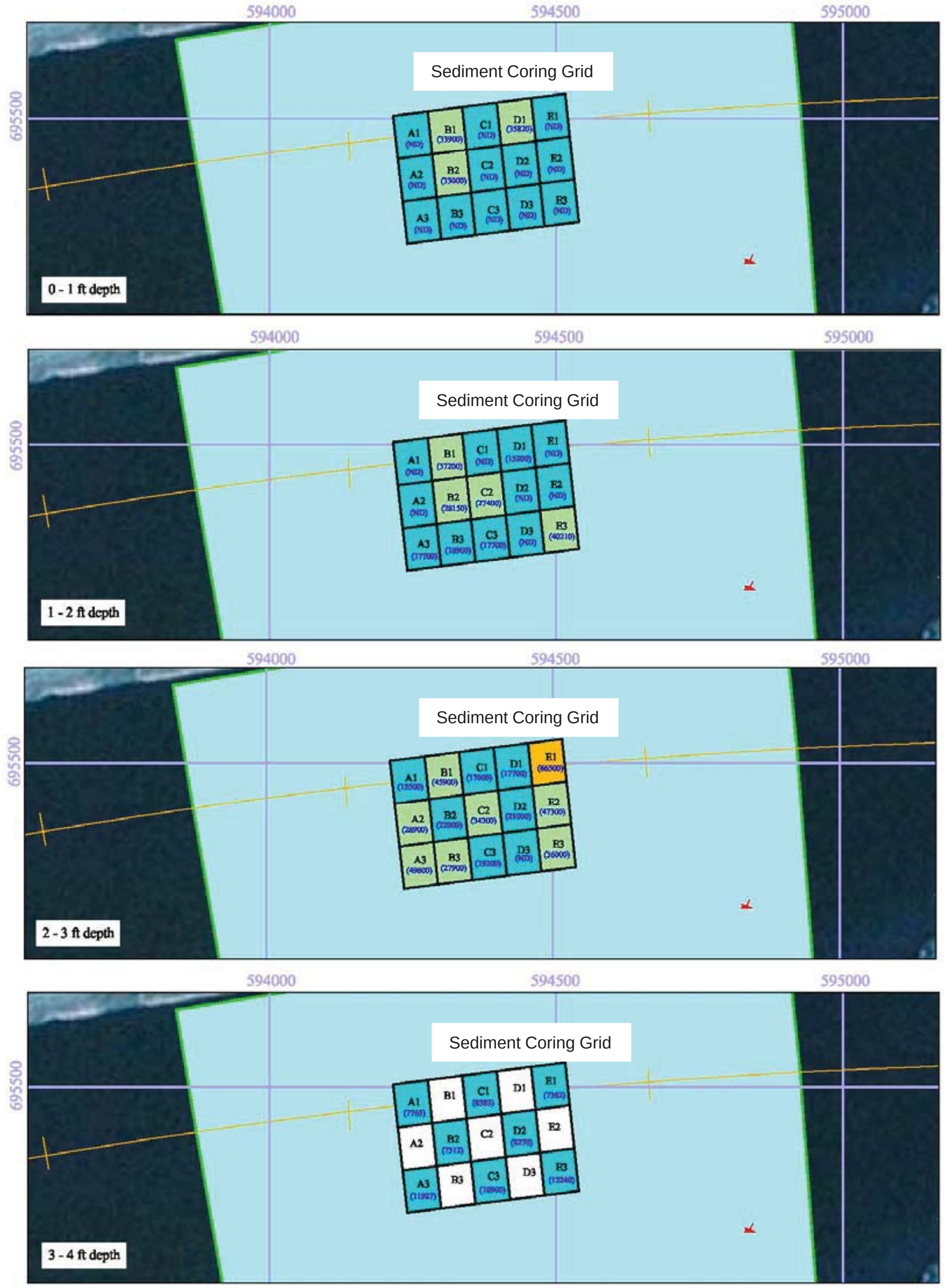
Lower Passaic River Restoration Project

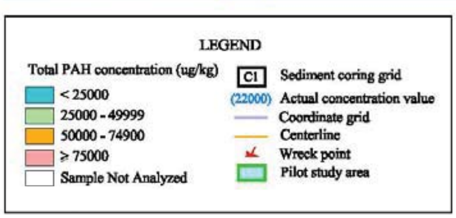
Figure 3-6

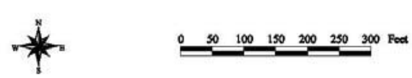
Proposed Dredge Area and Sediment Coring Grid
Lower Passaic River Restoration Project

Data Source:
1) Aerials, NJGIN, 2002

Figure 3-7





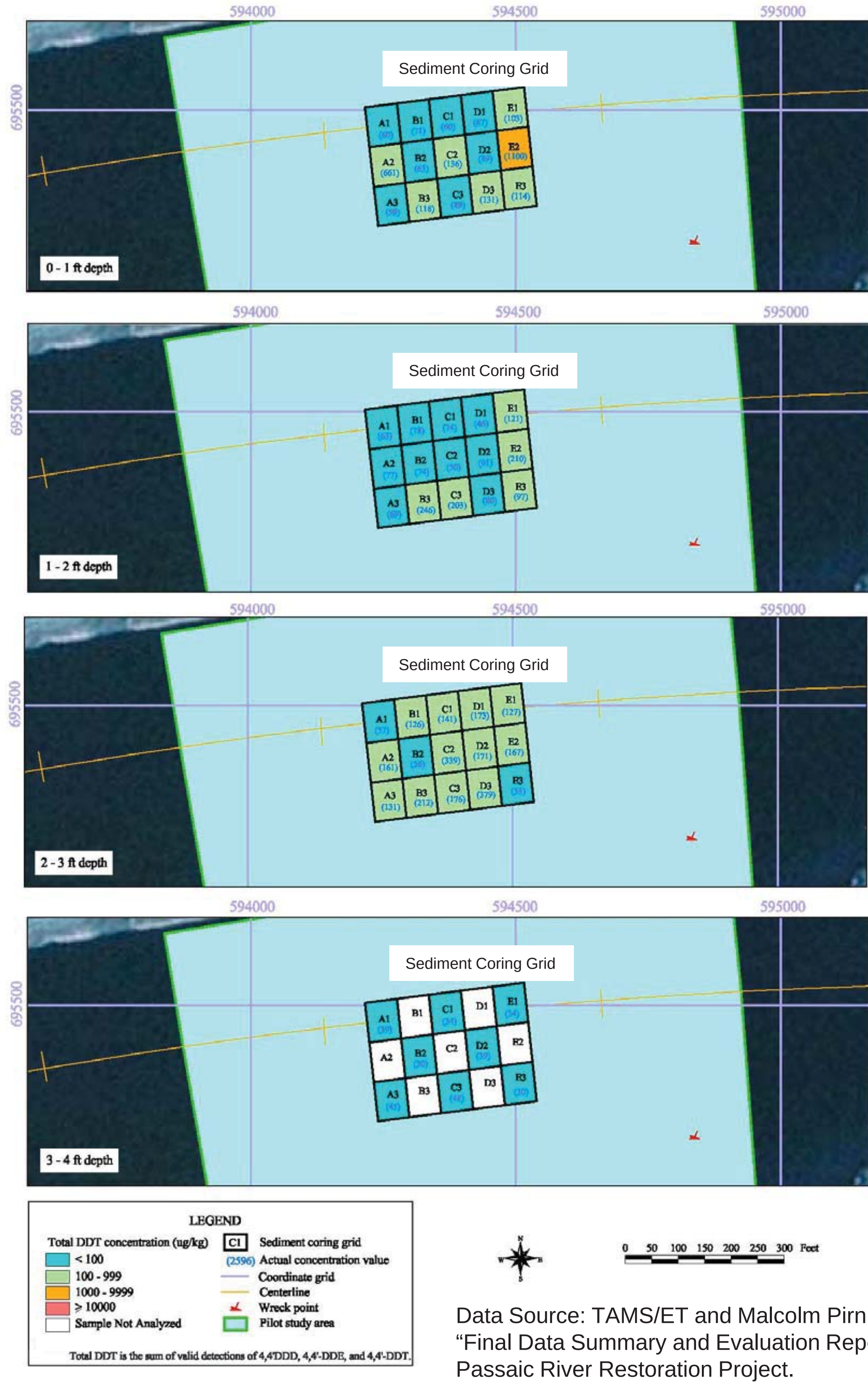


Data Source: TAMS/ET and Malcolm Pirnie, Inc., 2005b. "Final Data Summary and Evaluation Report." Lower Passaic River Restoration Project.

Total PAH Concentrations within Dredging Area

Lower Passaic River Restoration Project

Figure 3-8

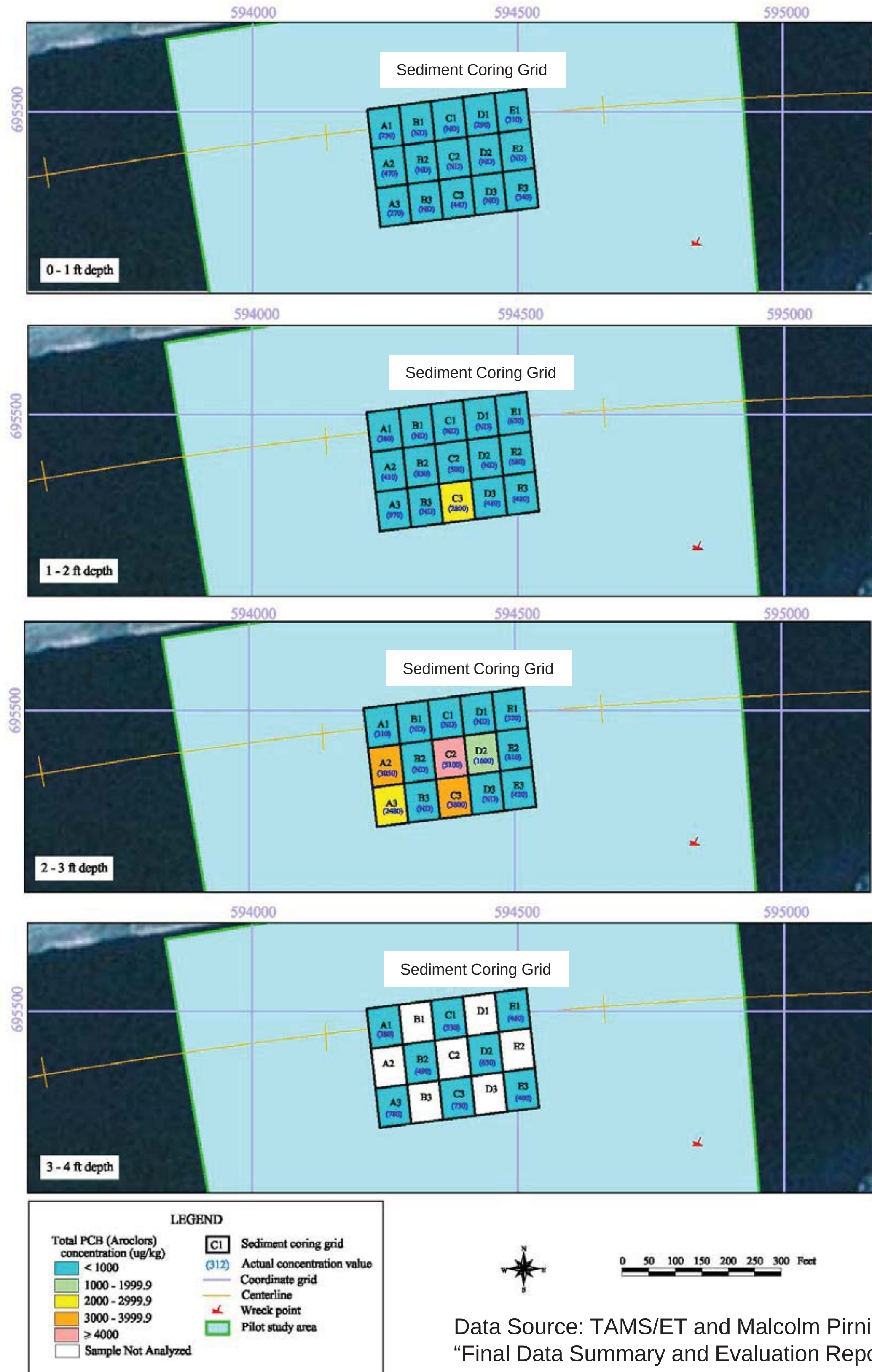


Data Source: TAMS/ET and Malcolm Pirnie, Inc., 2005b. “Final Data Summary and Evaluation Report.” Lower Passaic River Restoration Project.

Total DDT Concentrations within Dredging Area

Lower Passaic River Restoration Project

Figure 3-9

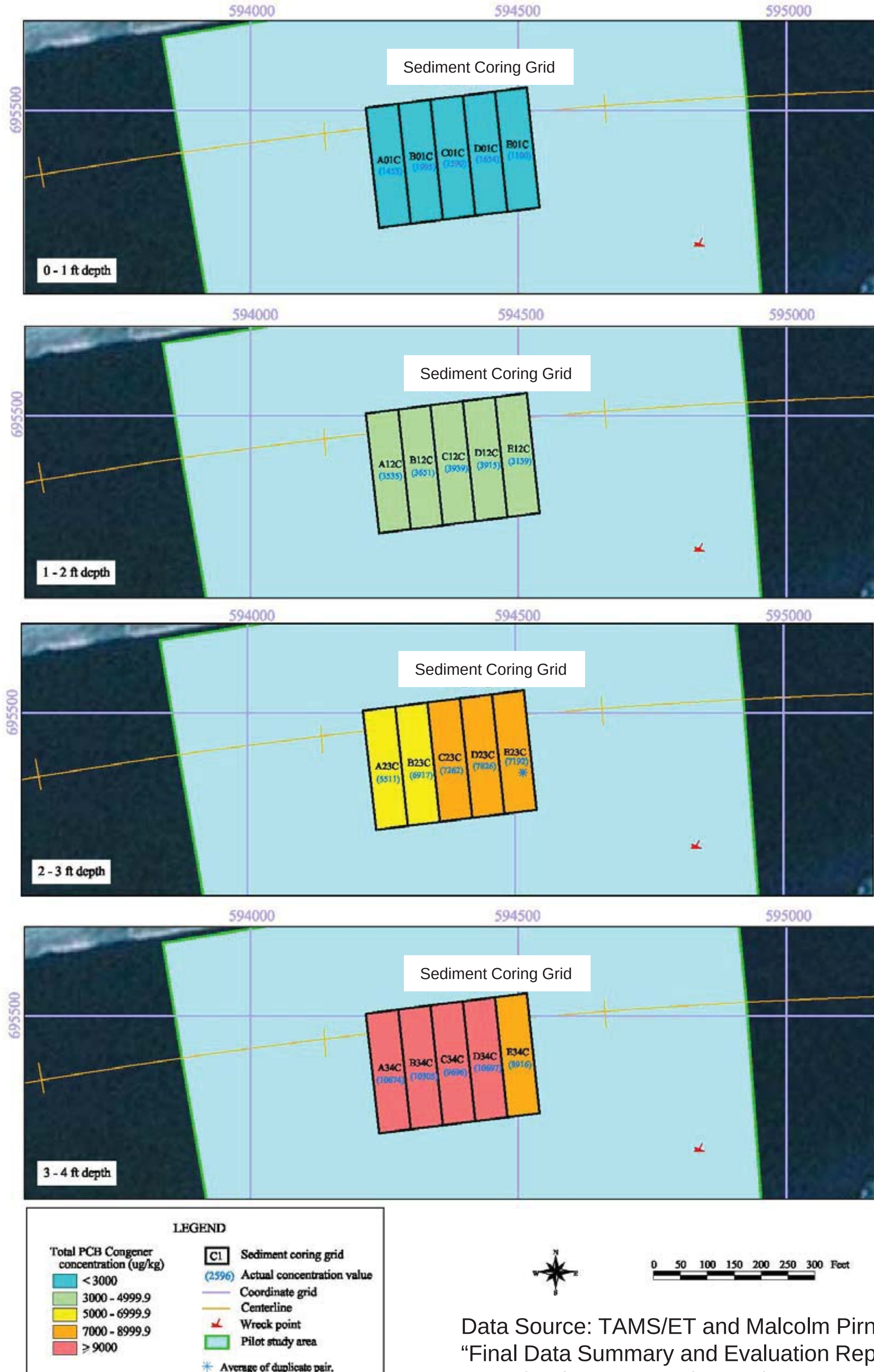


Data Source: TAMS/ET and Malcolm Pirnie, Inc., 2005b. “Final Data Summary and Evaluation Report.” Lower Passaic River Restoration Project.

Total PCB (Aroclors) Concentrations within Dredging Area

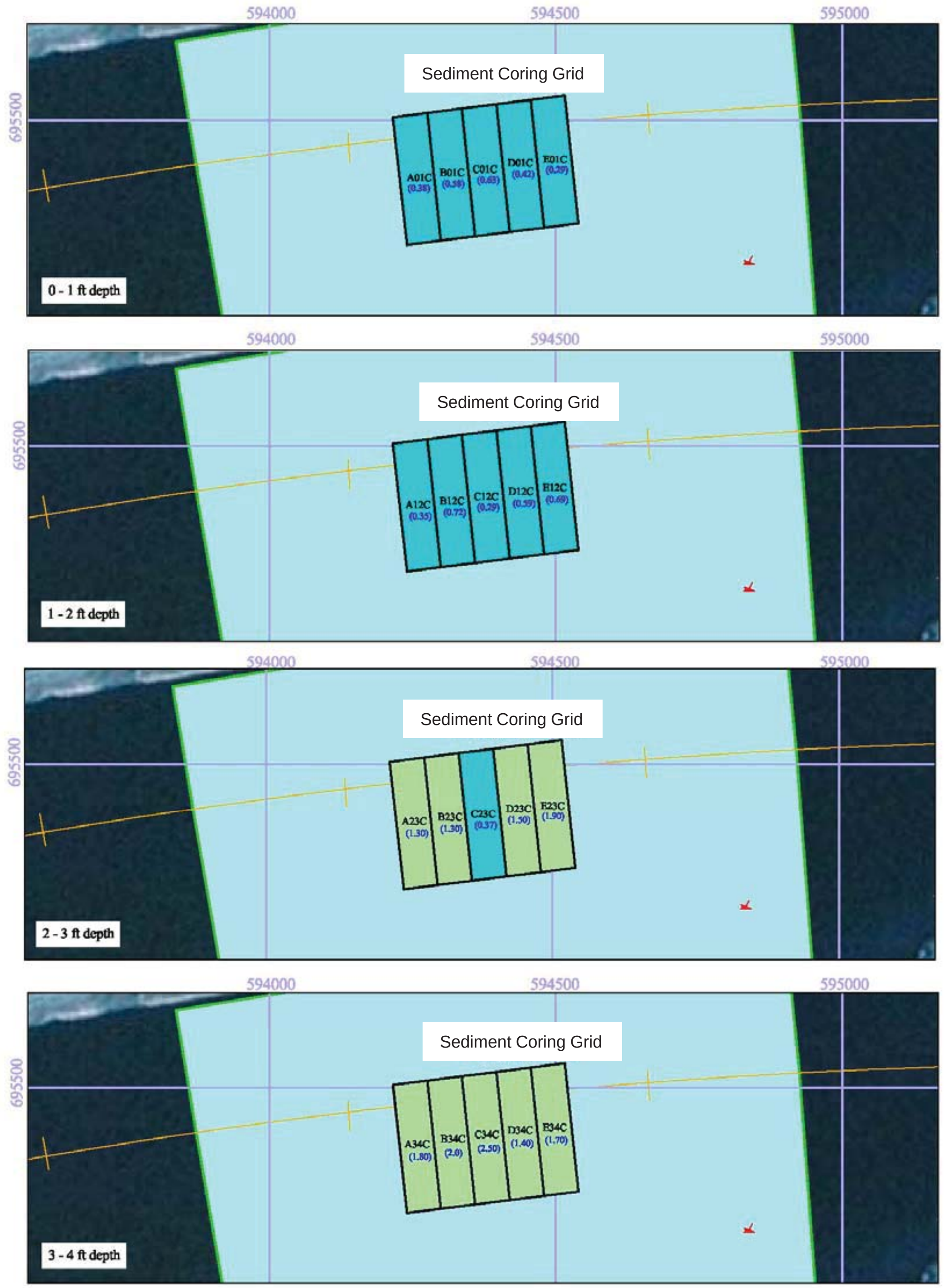
Lower Passaic River Restoration Project

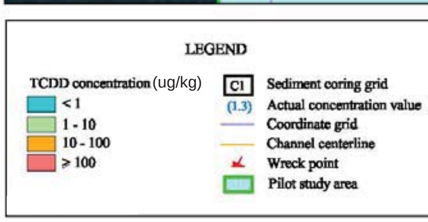
Figure 3-10

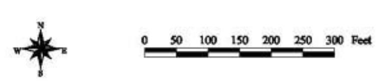


Data Source: TAMS/ET and Malcolm Pirnie, Inc., 2005b. "Final Data Summary and Evaluation Report." Lower Passaic River Restoration Project.

	Total PCB (Congeners) Concentrations within Dredging Area *Lower Passaic River Restoration Project*	Figure 3-11





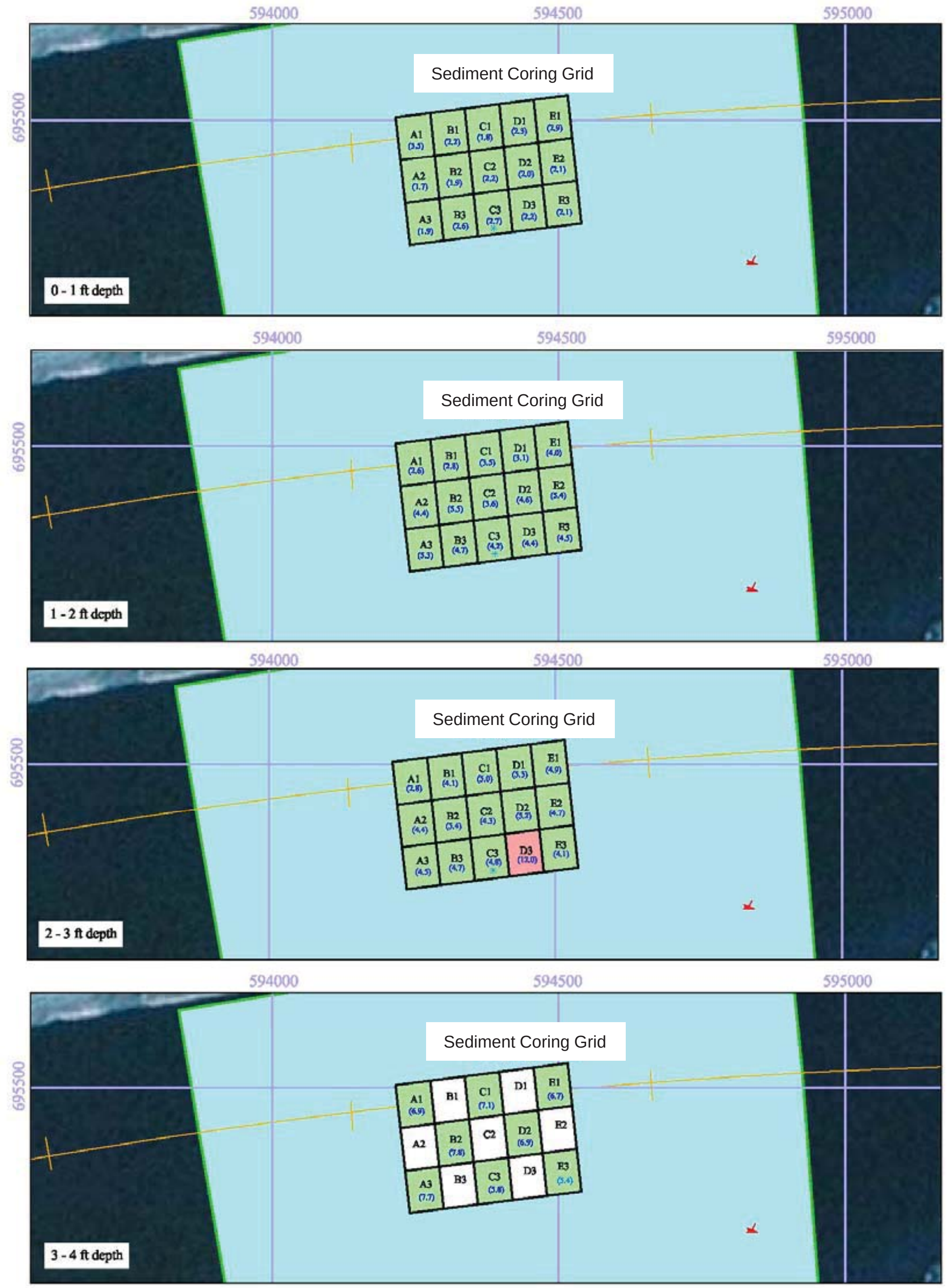


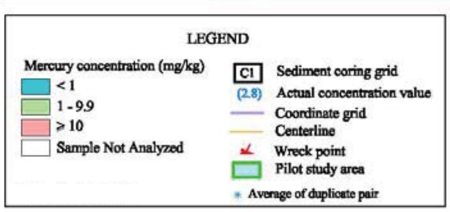
Data Source: TAMS/ET and Malcolm Pirnie, Inc., 2005b. “Final Data Summary and Evaluation Report.” Lower Passaic River Restoration Project.

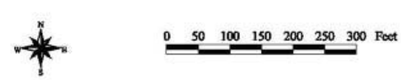
Total TCDD Concentrations within Dredging Area

Lower Passaic River Restoration Project

Figure 3-12





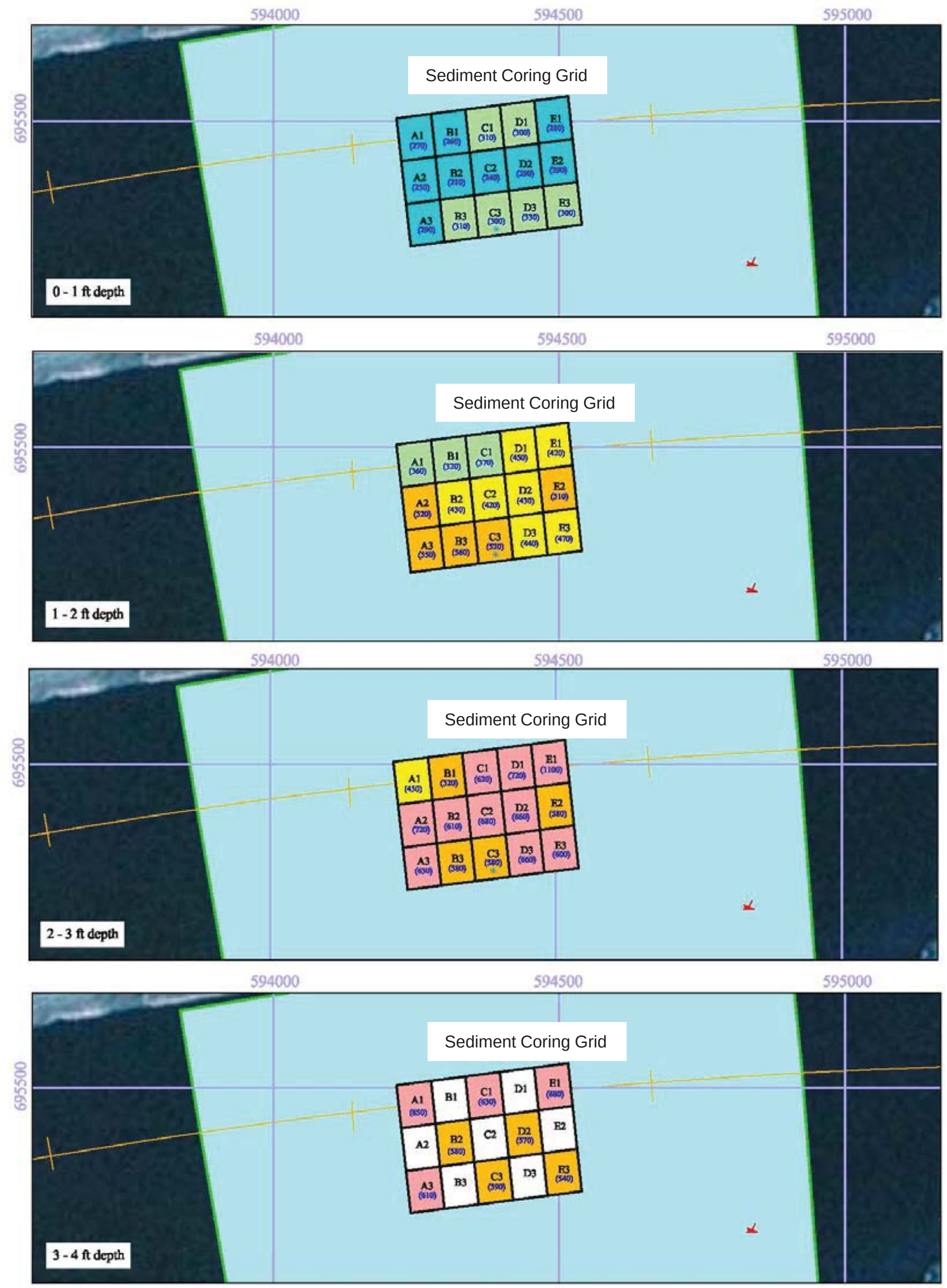


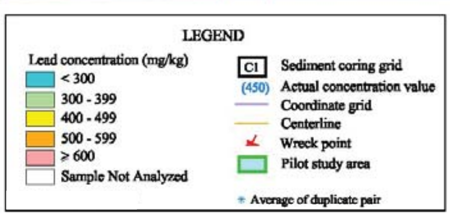
Data Source: TAMS/ET and Malcolm Pirnie, Inc., 2005b. "Final Data Summary and Evaluation Report." Lower Passaic River Restoration Project.

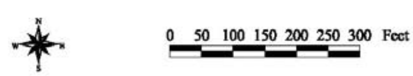
Mercury Concentrations within Dredging Area

Lower Passaic River Restoration Project

Figure 3-13





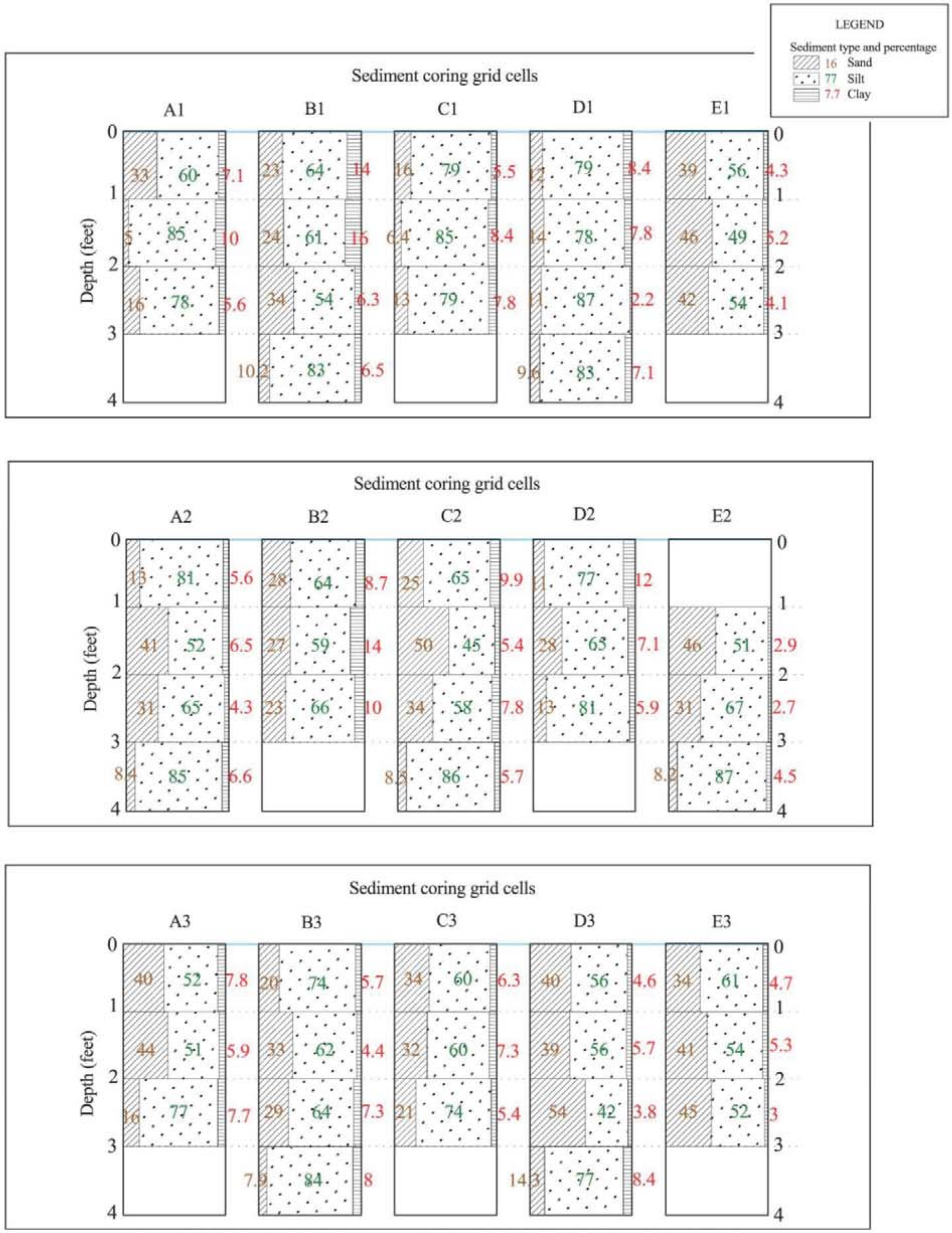


Data Source: TAMS/ET and Malcolm Pirnie, Inc., 2005b. “Final Data Summary and Evaluation Report.” Lower Passaic River Restoration Project.

Lead Concentrations within Dredging Area

Lower Passaic River Restoration Project

Figure 3-14



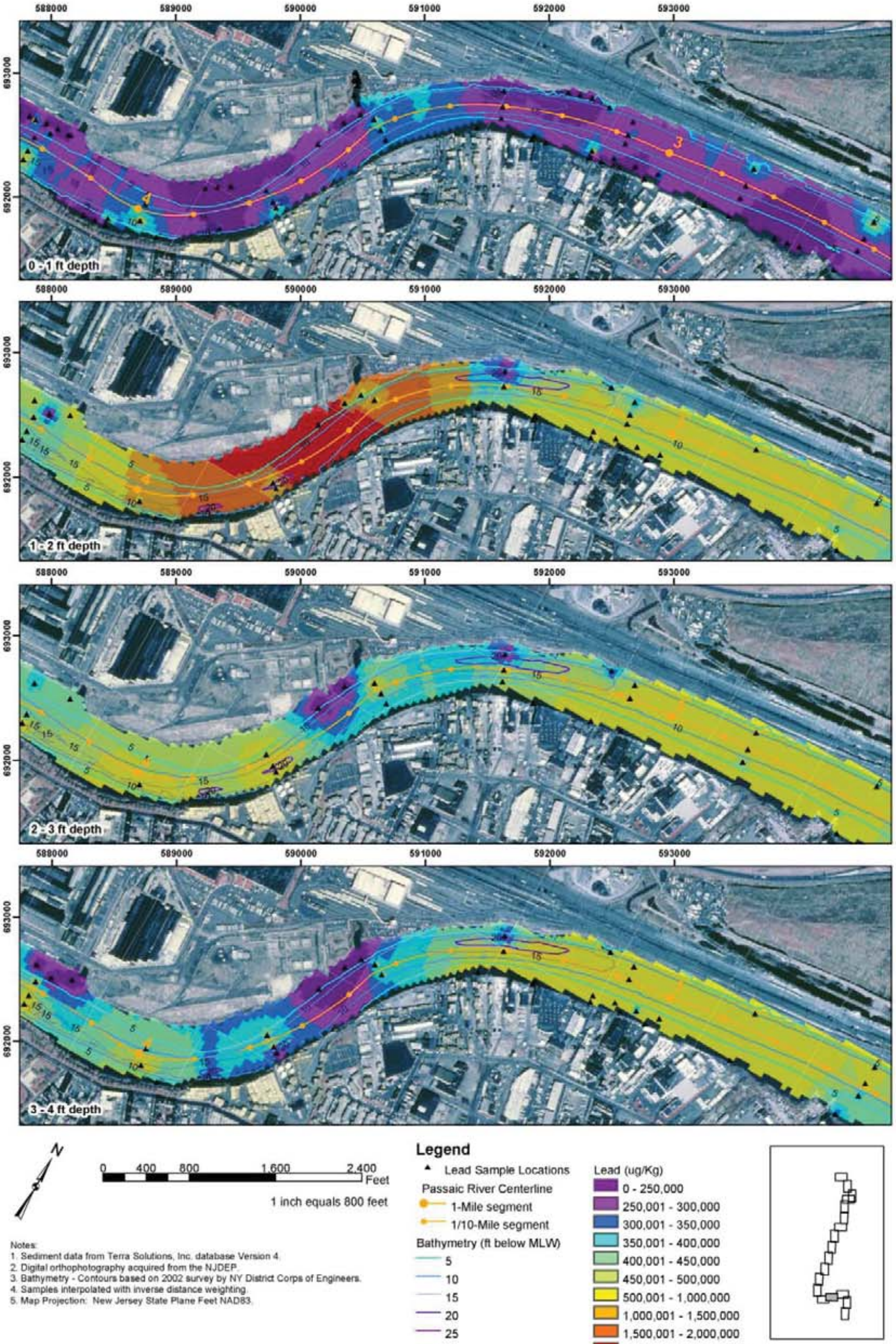
Note: B1-23 also included 5.5% Granule, >2mm. This fraction was not significant (i.e., ≤0.2%) in all other samples.

Data Source: TAMS/ET and Malcolm Pirnie, Inc., 2005. "Final Data Summary and Evaluation Report." Lower Passaic River Restoration Project.

Cross-Section of Sediment Coring Grid Cells Showing Sediment Type and Percentage

Lower Passaic River Restoration Project

Figure 3-15

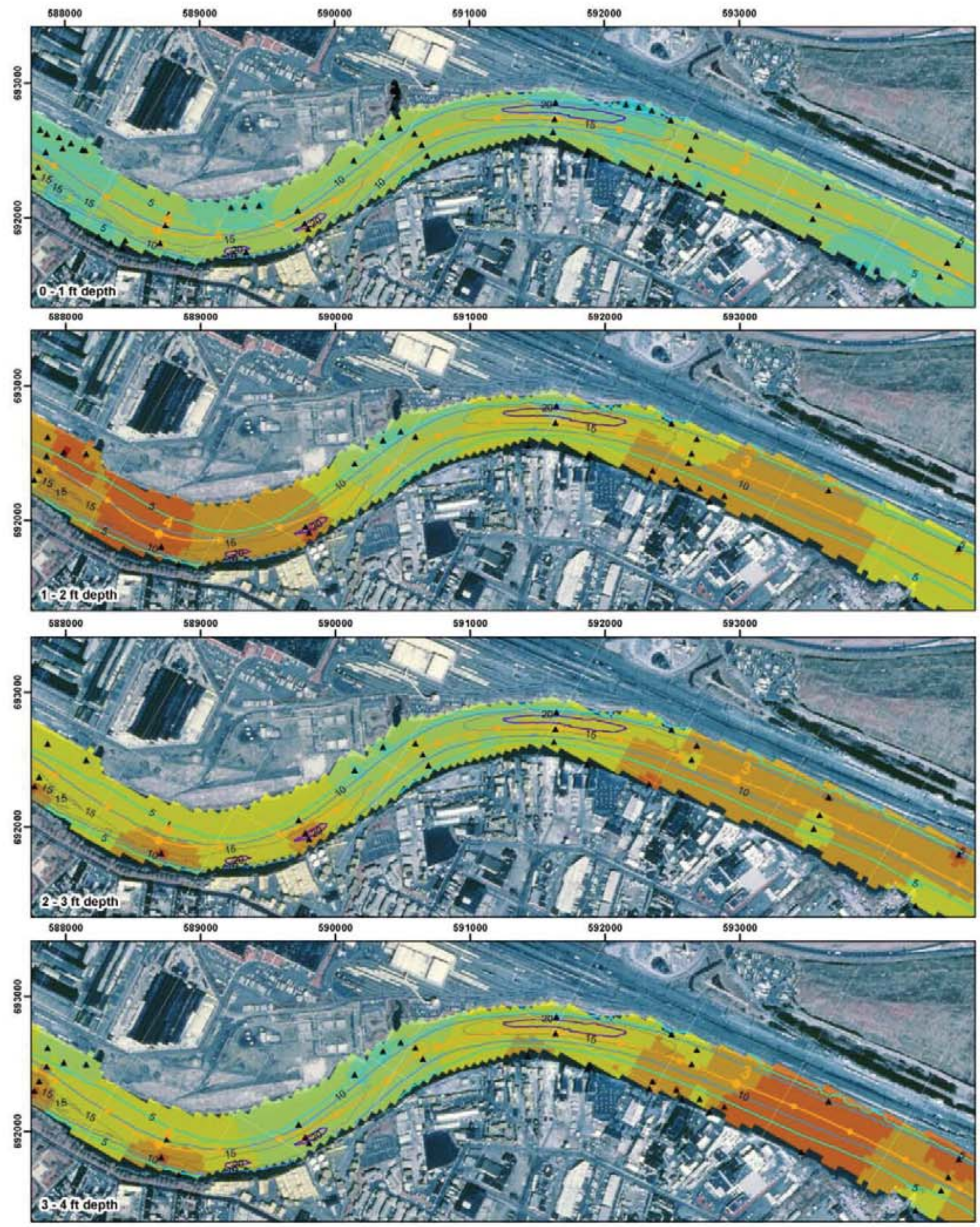


Notes:
1. Sediment data from Terra Solutions, Inc. database Version 4.
2. Digital orthophotography acquired from the NJDEP.
3. Bathymetry - Contours based on 2002 survey by NY District Corps of Engineers.
4. Samples interpolated with inverse distance weighting.
5. Map Projection: New Jersey State Plane Feet NAD83.

Lead Sediment Concentrations (0-4 feet) from RM2.7 to RM4.1

Figure 3-16

Lower Passaic River Restoration Project



N

0 400 800 1,600 2,400 Feet

1 inch equals 800 feet

Notes:
1. Sediment data from Terra Solutions, Inc. database Version 4.
2. Digital orthophotography acquired from the NJDEP.
3. Bathymetry - Contours based on 2002 survey by NY District Corps of Engineers.
4. Samples interpolated with inverse distance weighting.
5. Map Projection: New Jersey State Plane Feet NAD83.

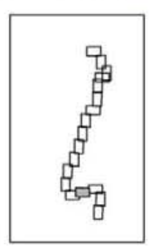
Legend

▲ Mercury Sample Locations

Passaic River Centerline
- 1-Mile segment
- 1/10-Mile segment

Bathymetry (ft below MLW)
- 5
- 10
- 15
- 20
- 25
- 30

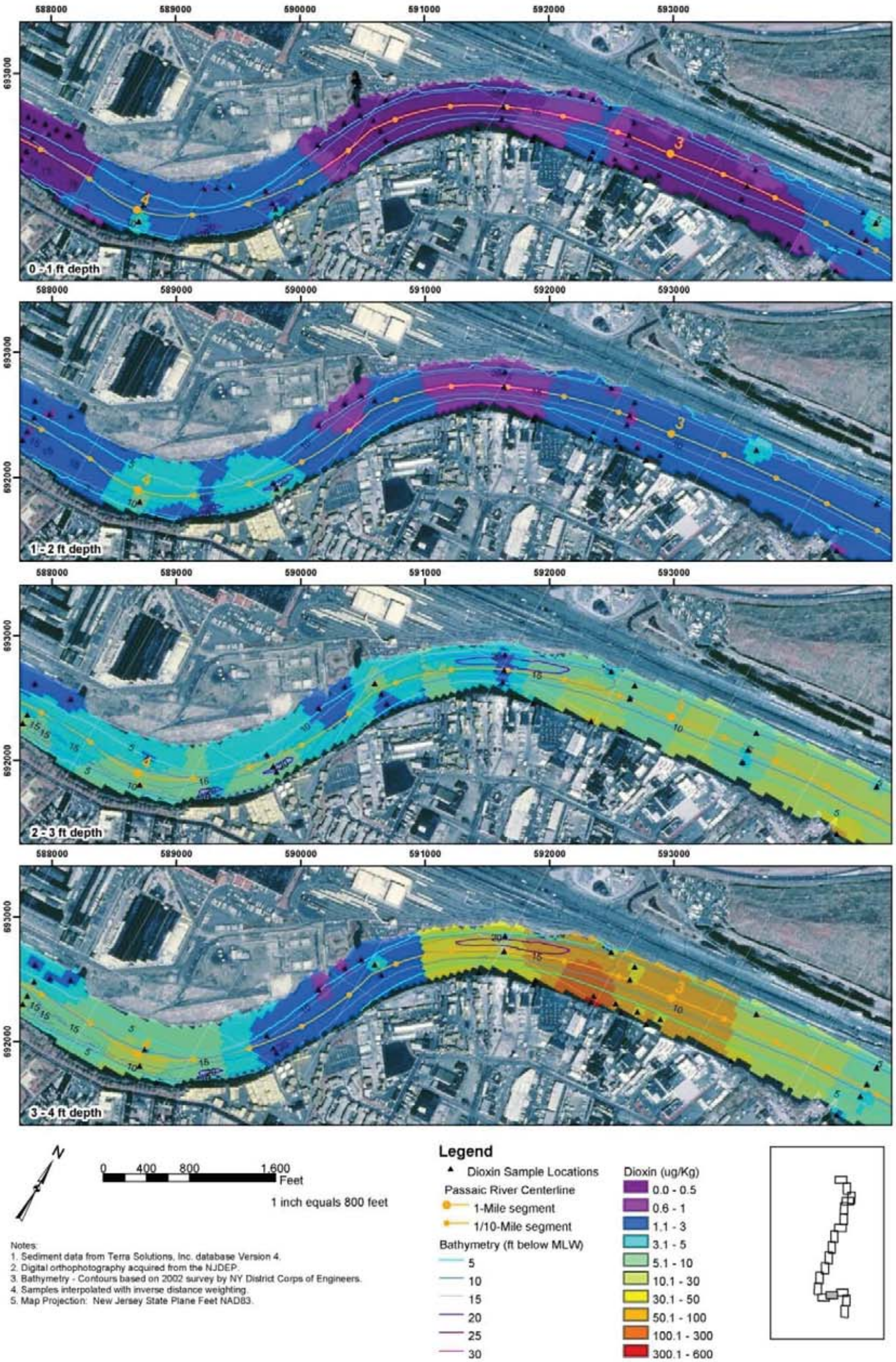
Mercury (ug/Kg)
- 0 - 10
- 11 - 100
- 101 - 500
- 501 - 1,000
- 1,001 - 2,500
- 2,501 - 5,000
- 5,001 - 7,500
- 7,501 - 10,000
- 10,001 - 17,500
- 17,501 - 25,000



Mercury Sediment Concentrations (0-4 feet) from RM2.7 to RM4.1

Figure 3-17

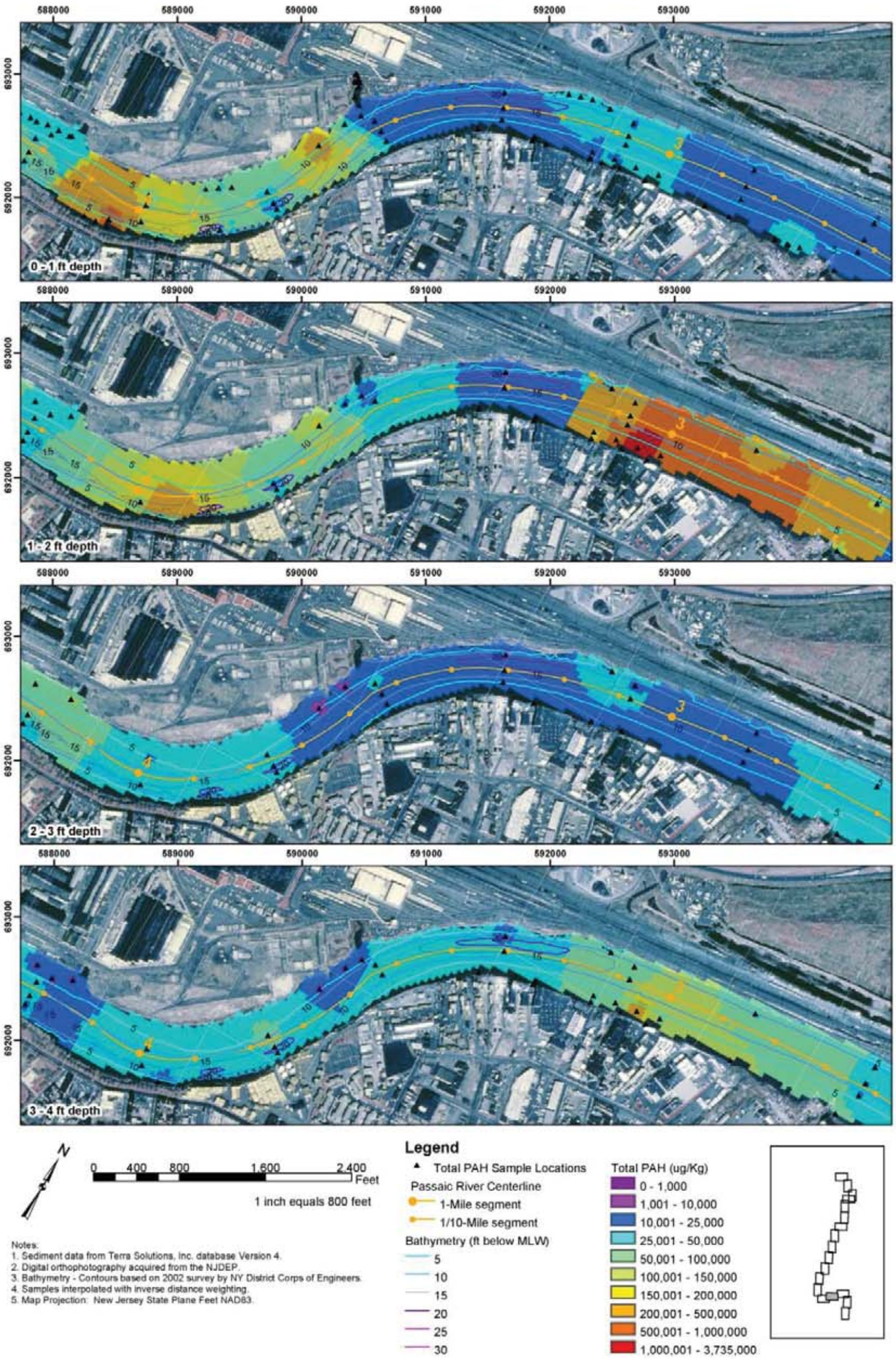
Lower Passaic River Restoration Project



2,3,7,8-TCDD Sediment Concentrations (0-4 feet) from RM2.7 to RM4.1

Lower Passaic River Restoration Project

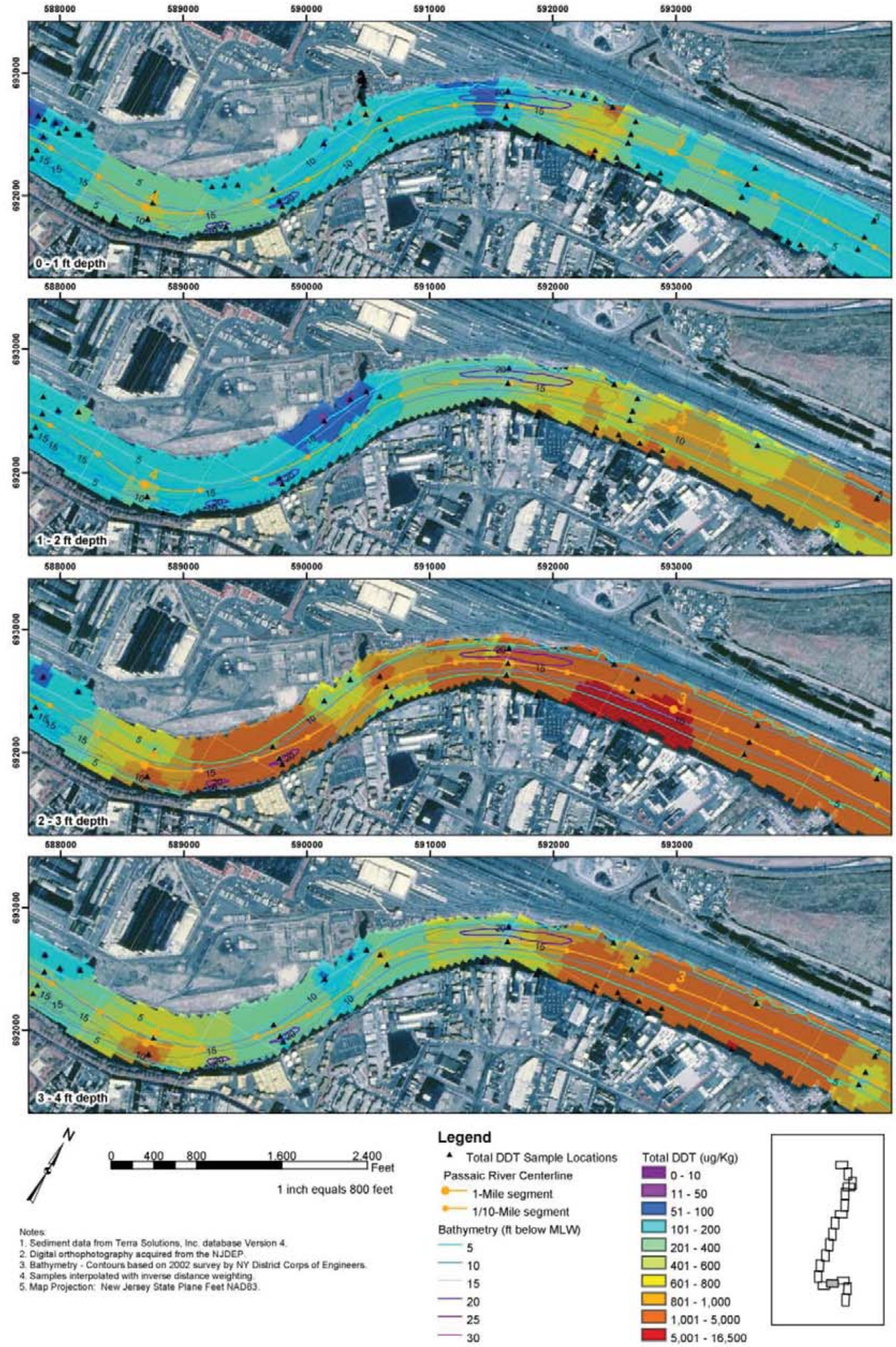
Figure 3-18



Total PAH Sediment Concentrations (0-4 feet) from RM2.7 to RM4.1

Lower Passaic River Restoration Project

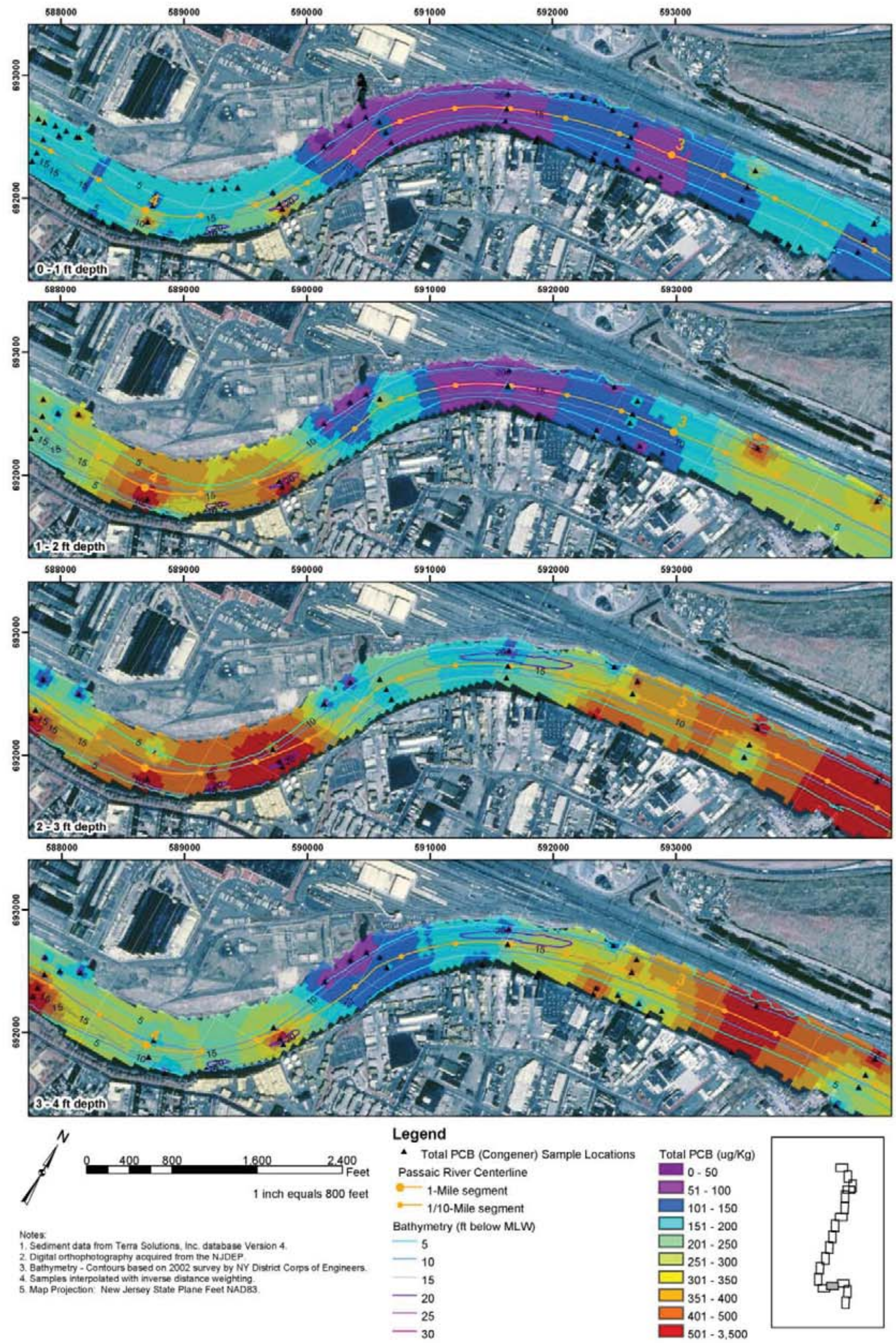
Figure 3-19



Total DDT Sediment Concentrations (0-4 feet) from RM2.7 to RM4.1

Lower Passaic River Restoration Project

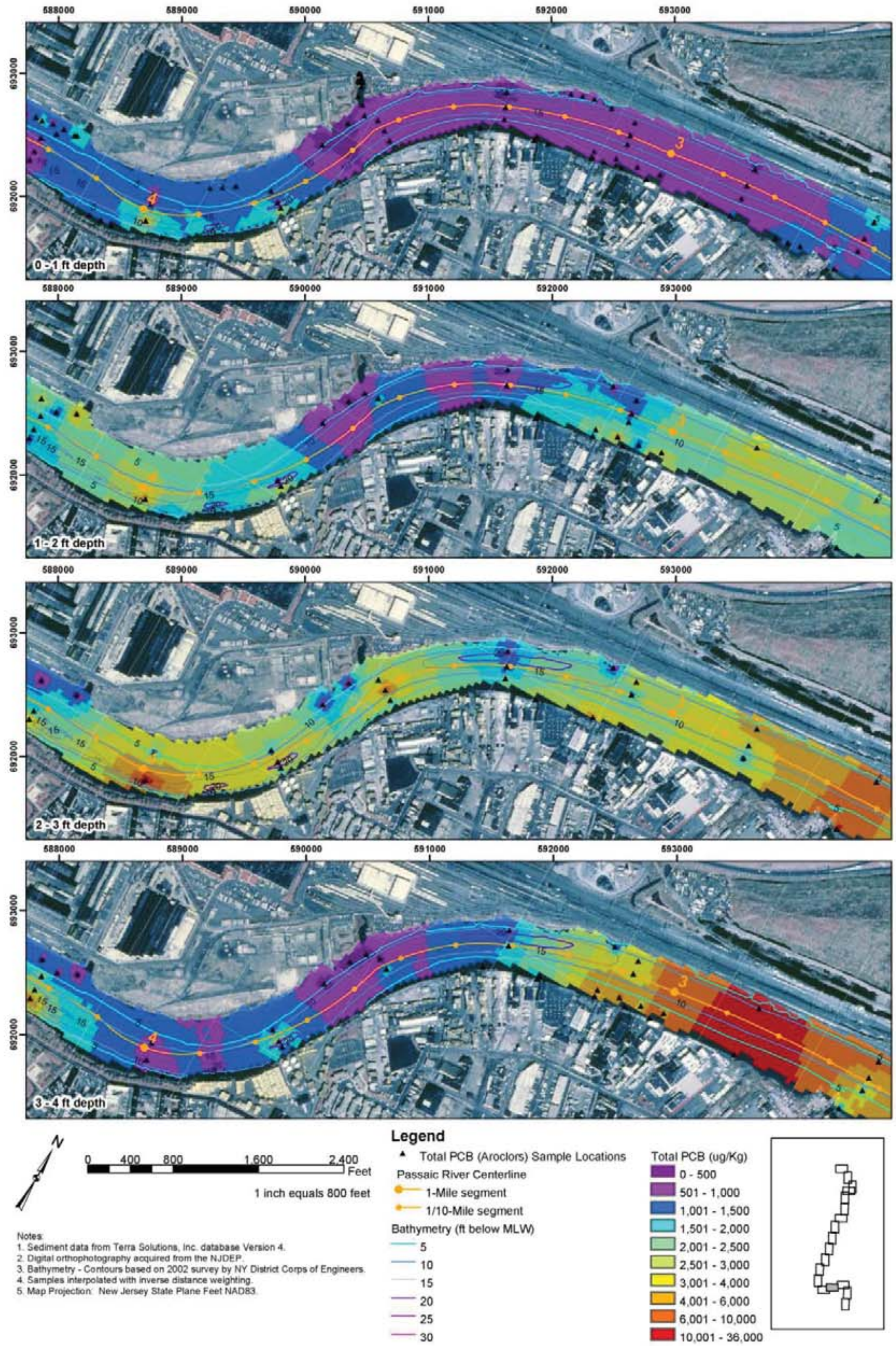
Figure 3-20



Total PCB (Coplanar Congeners) Sediment Concentrations (0-4 feet) from RM2.7 to RM4.1

Lower Passaic River Restoration Project

Figure 3-21



Total PCB (Aroclors) Sediment Concentrations (0-4 feet) from RM2.7 to RM4.1

Lower Passaic River Restoration Project

Figure 3-22

Dredging equipment at Pilot Study Area

Photographs of Dredging Operations

Lower Passaic River Restoration Project

Figure 4-1a

Photographs of Dredging Operations

Lower Passaic River Restoration Project

Figure 4-1b

Photographs of Dredging Operations

Lower Passaic River Restoration Project

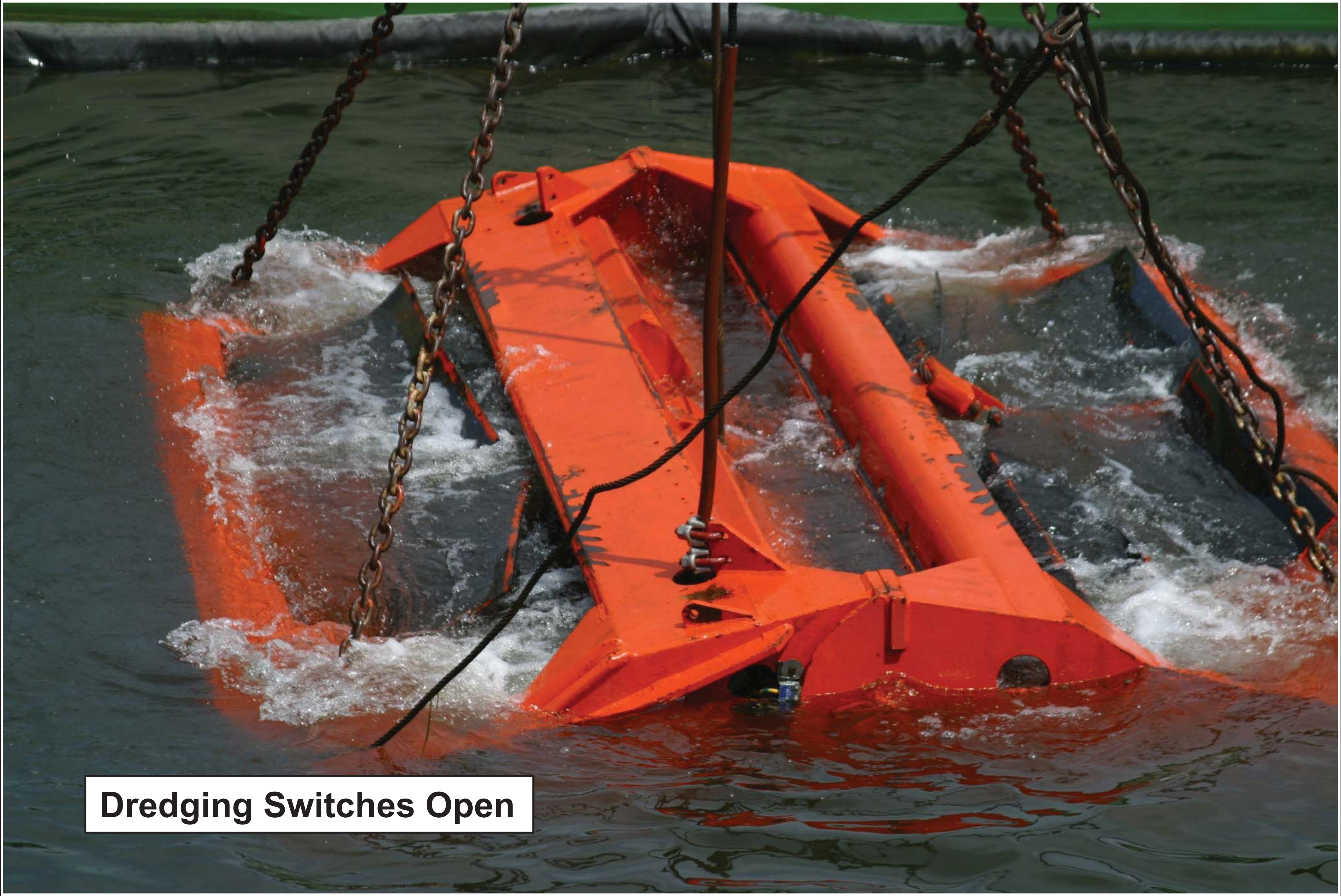
Figure 4-1c

Clamshell bucket and scow

Photographs of Dredging Operations

Lower Passaic River Restoration Project

Figure 4-1d



Photographs of Dredging Operations

Lower Passaic River Restoration Project

Figure 4-1e

Photographs of Dredging Operations

Lower Passaic River Restoration Project

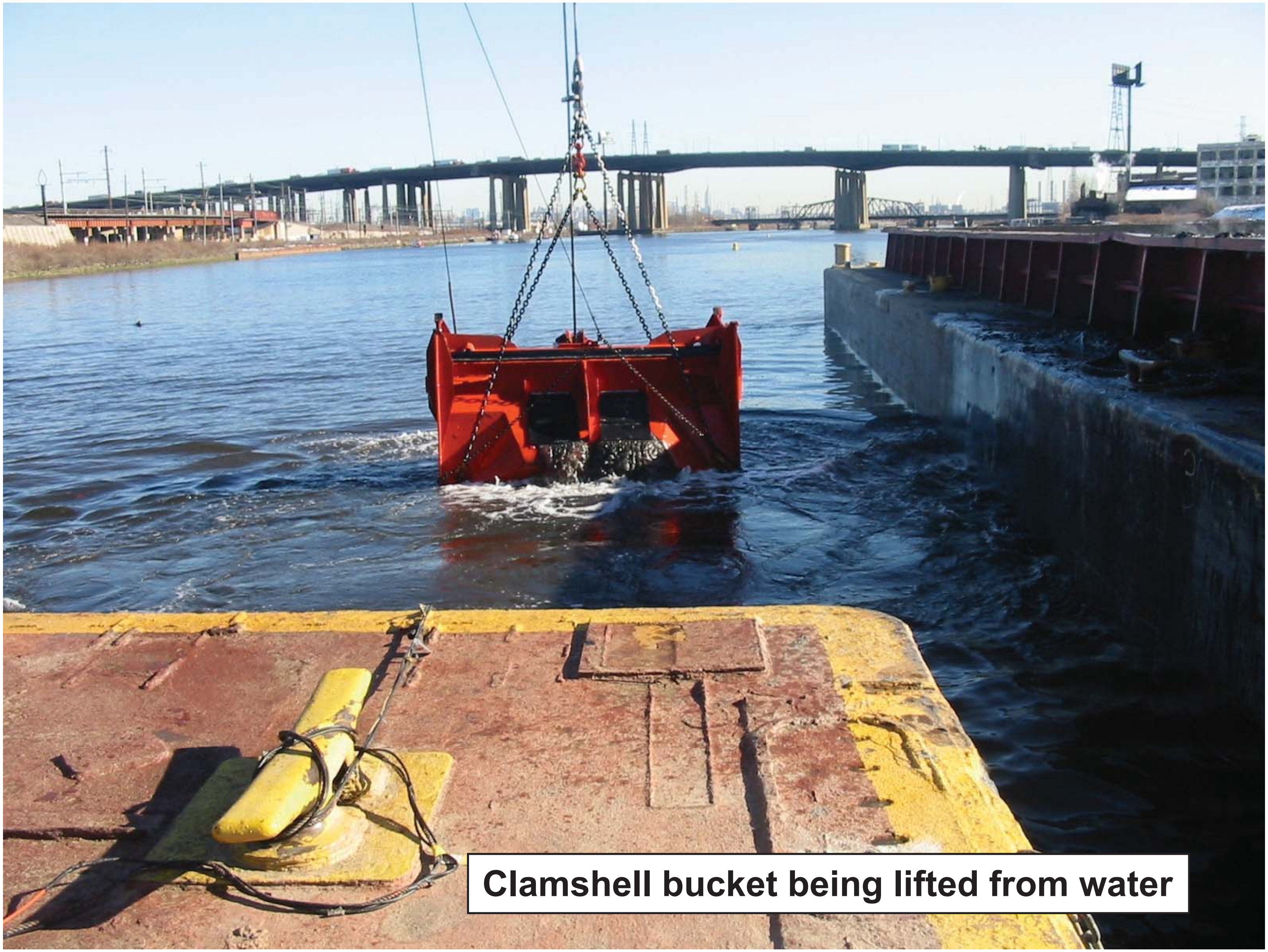
Figure 4-1f


Clamshell bucket being lifted from water

Photographs of Dredging Operations

Lower Passaic River Restoration Project

Figure 4-1g



Photographs of Dredging Operations

Lower Passaic River Restoration Project

Figure 4-1h

Photographs of Dredging Operations

Lower Passaic River Restoration Project

Figure 4-1i

Dredged material placed in scow

Photographs of Dredging Operations

Lower Passaic River Restoration Project

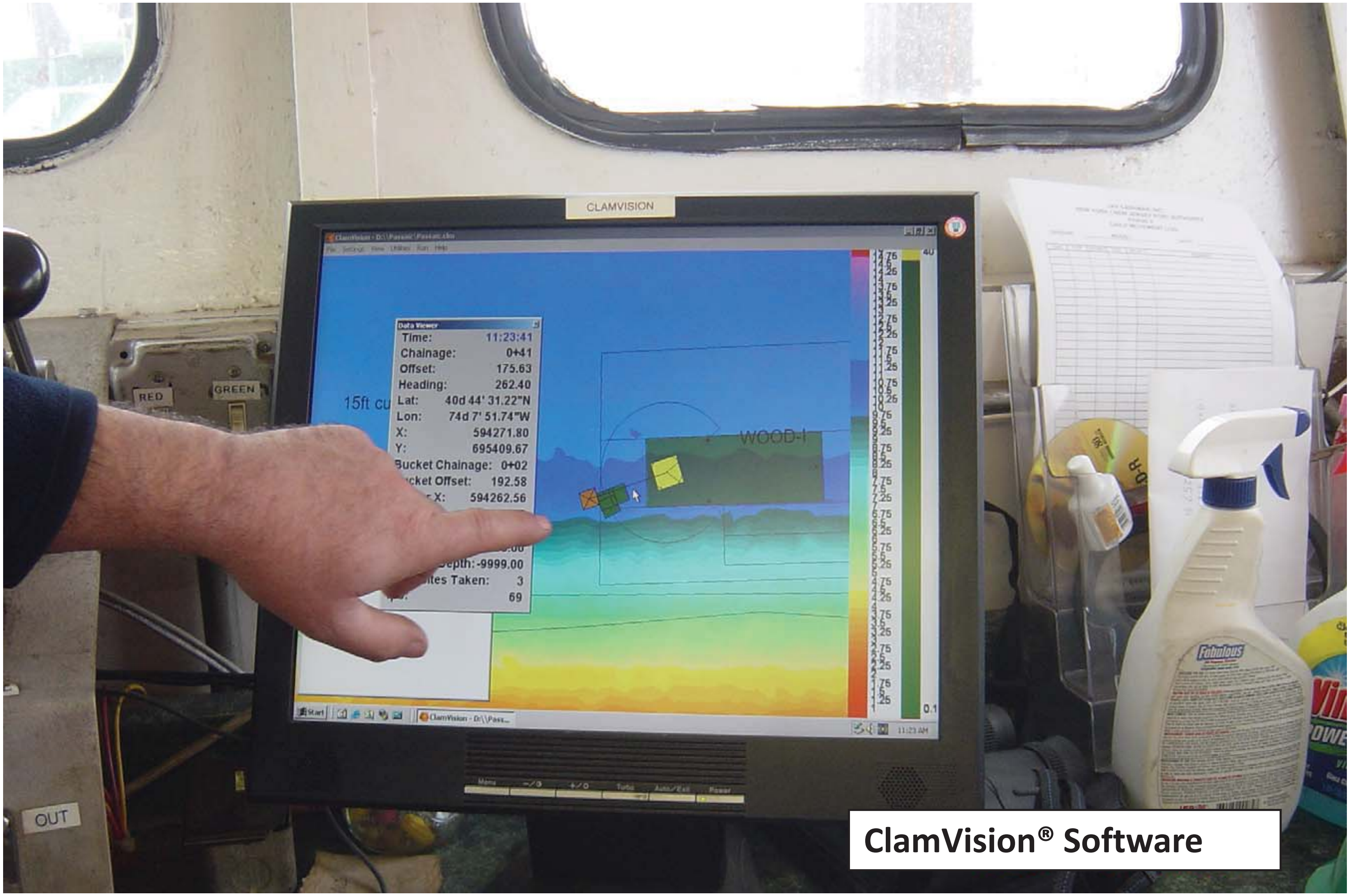
Figure 4-1j

Dredged material placed in scow

Photographs of Dredging Operations

Lower Passaic River Restoration Project

Figure 4-1k



ClamVision® Software

Photographs of Dredging Operations

Lower Passaic River Restoration Project

Figure 4-1l

Water quality monitoring program near dredging

Photographs of Dredging Operations

Lower Passaic River Restoration Project

Figure 4-1m

Water quality monitoring program near dredging

Photographs of Dredging Operations

Lower Passaic River Restoration Project

Figure 4-1n

Photographs of Dredging Operations

Lower Passaic River Restoration Project

Figure 4-1o

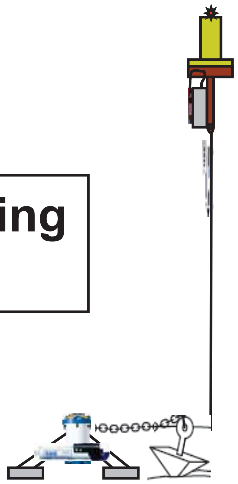
Trace Organic Platform Samplers (TOPS) and ISCO Samplers

Photographs of Dredging Operations

Lower Passaic River Restoration Project

Figure 4-1p

Schematic of mooring deployment



Acoustic Doppler Current Profiler (ADCP),
Optical Backscatter (OBS),
Conductivity Temperature Depth Sensors (CTD)

Photographs of Dredging Operations

Lower Passaic River Restoration Project

Figure 4-1q

Dredging on December 9, 2005 was cancelled due to weather

Photographs of Dredging Operations

Lower Passaic River Restoration Project

Figure 4-1r

Photographs of Dredging Operations

Lower Passaic River Restoration Project

Figure 4-1s

Bucket depth sensor

GPS receiver

Boom angle indicator

Barge GPS

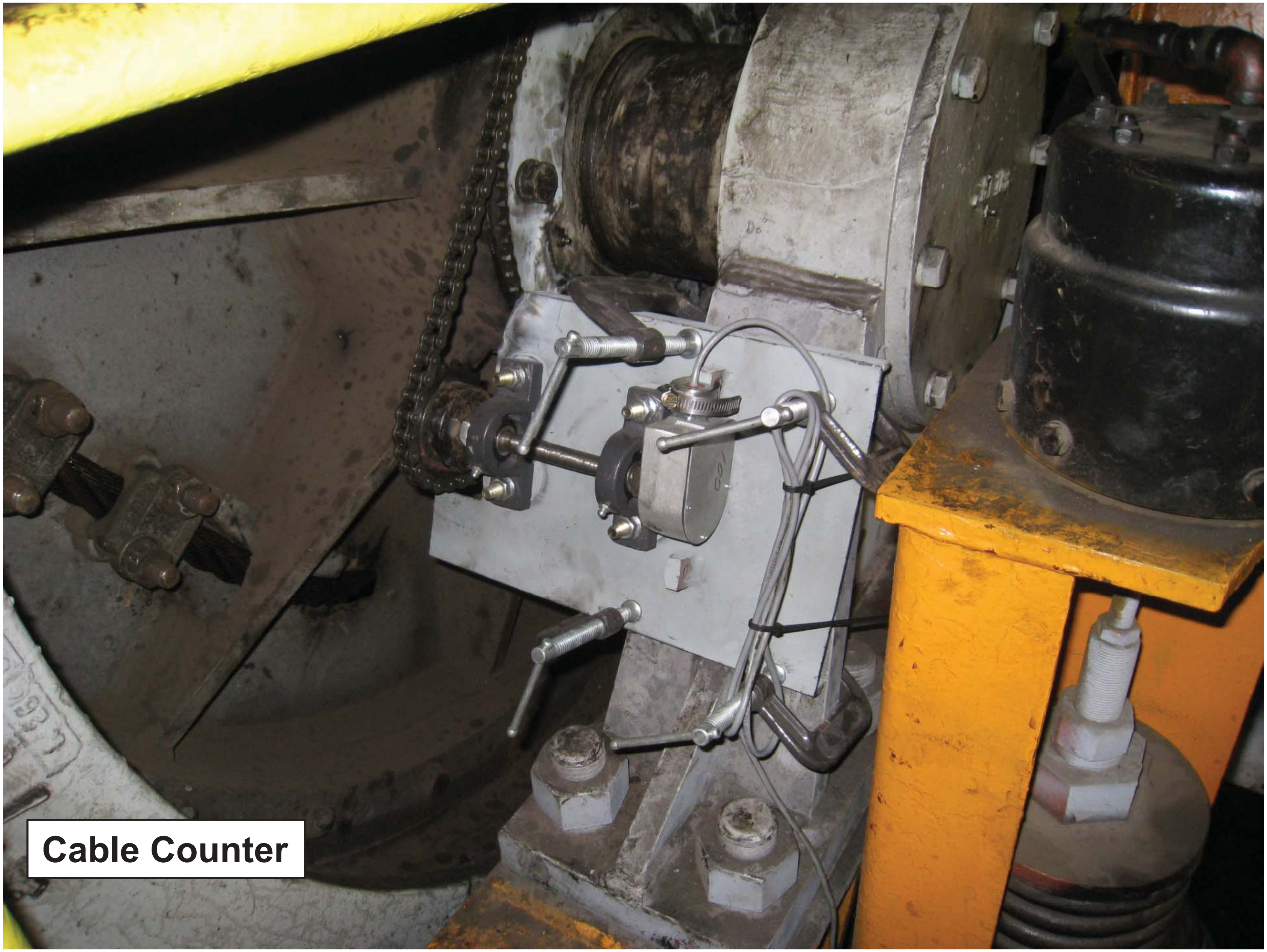
GPS antennae

Barge GPS

Photographs of Dredging Operations

Lower Passaic River Restoration Project

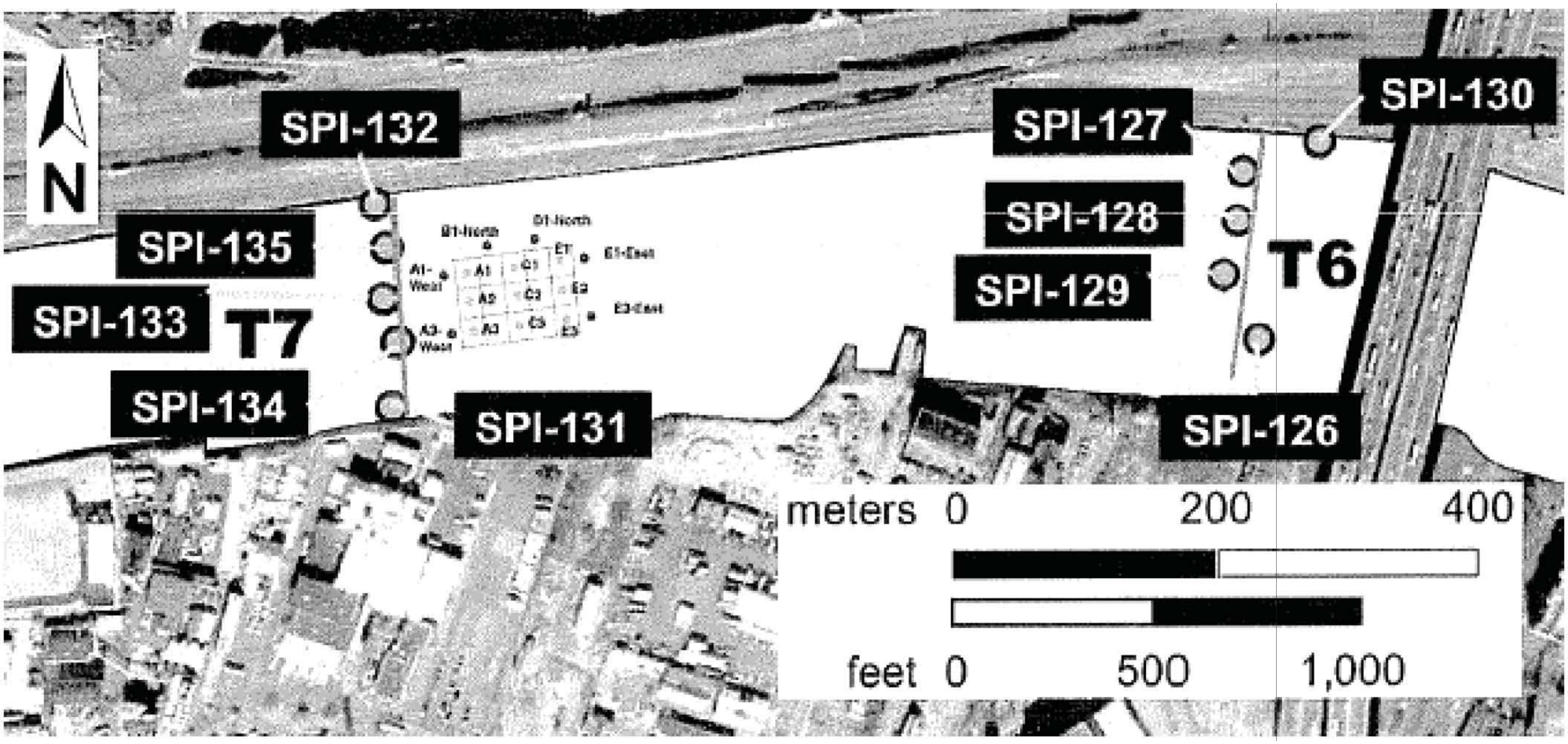
Figure 4-1t



Photographs of Dredging Operations

Lower Passaic River Restoration Project

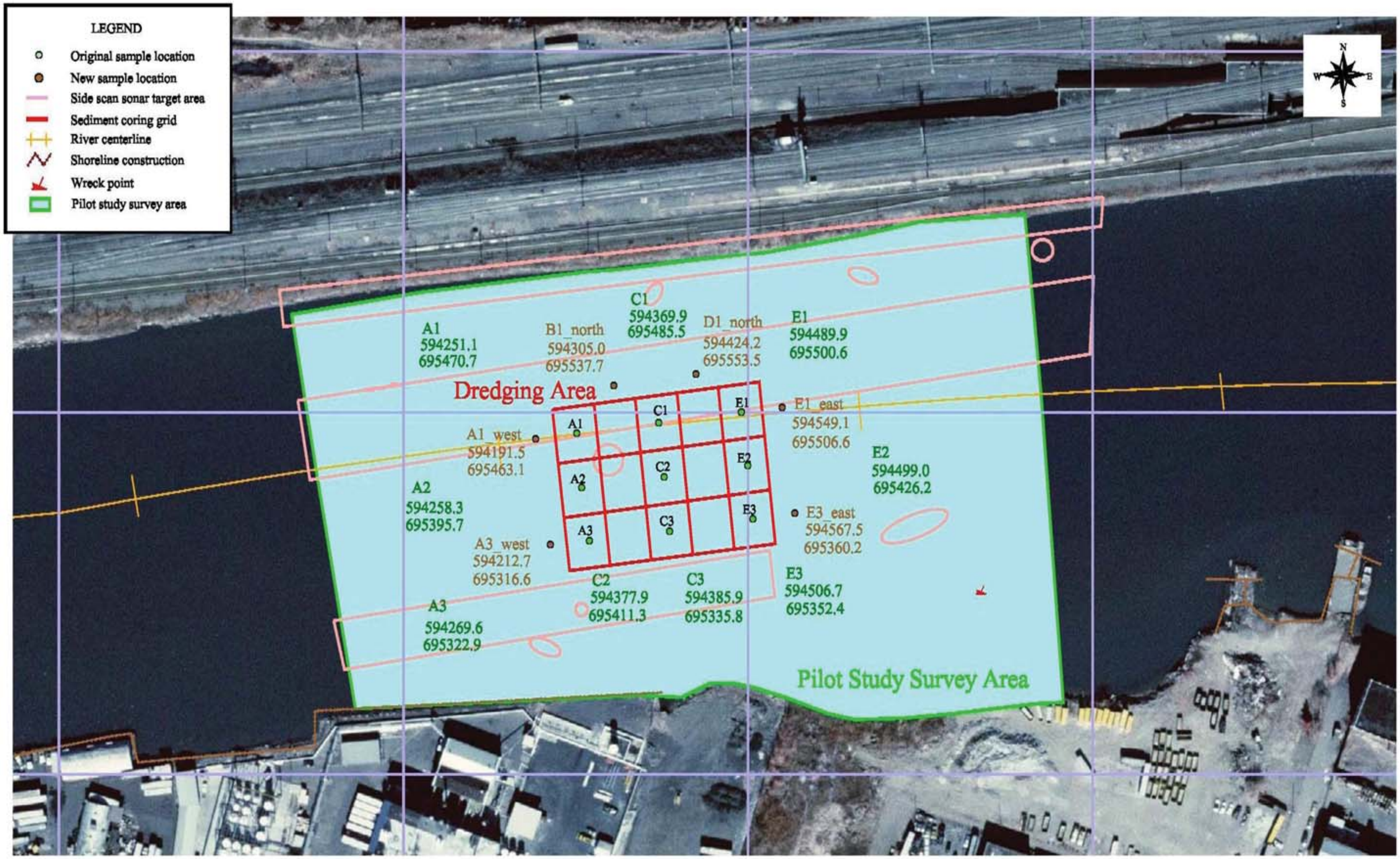
Figure 4-1u



Map of Sediment Profile Imaging Sampling Locations (June 2005)

Lower Passaic River Restoration Project

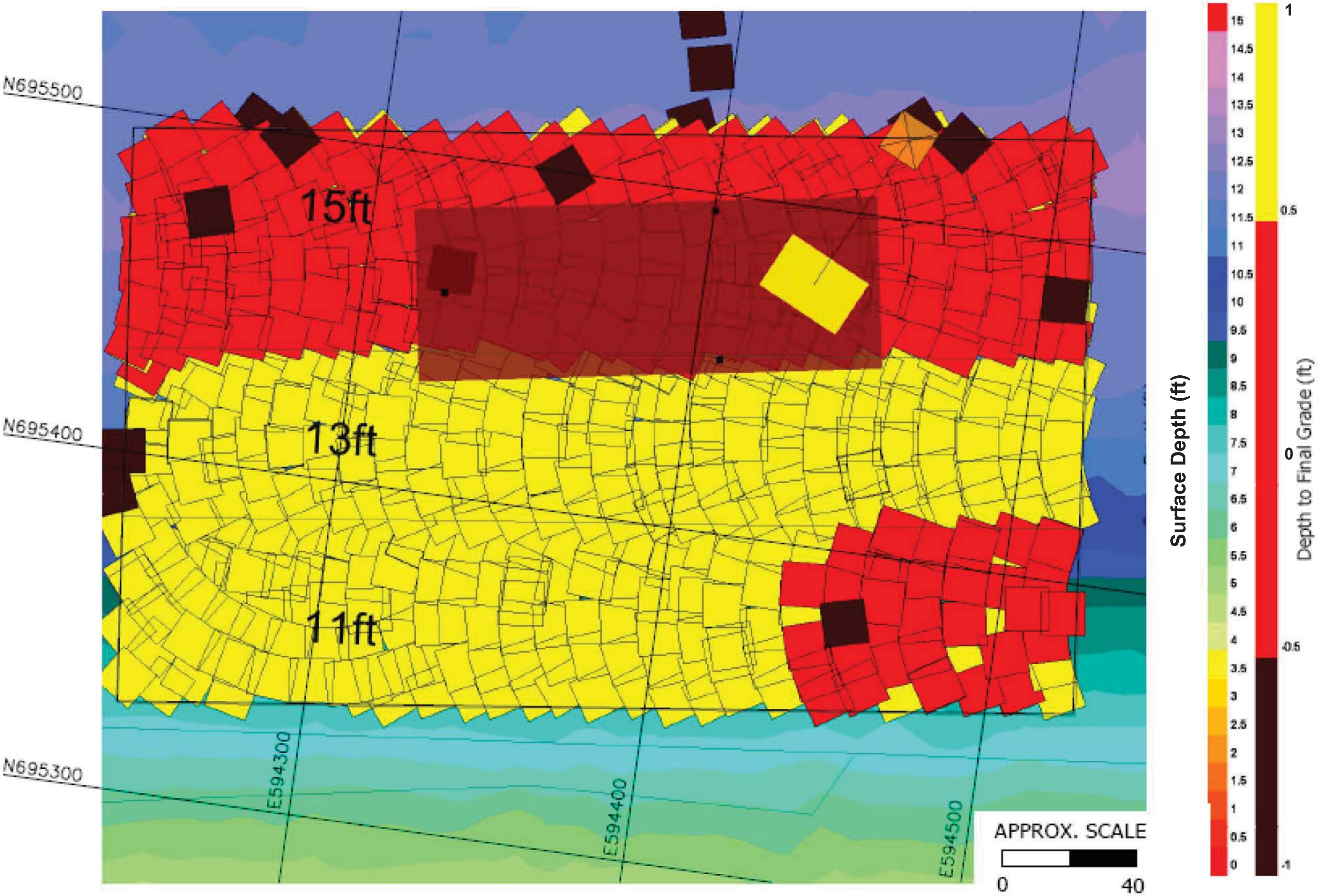
Figure 4-2



Map of Sediment Profile Imaging Sampling Locations (December 2005)

Lower Passaic River Restoration Project

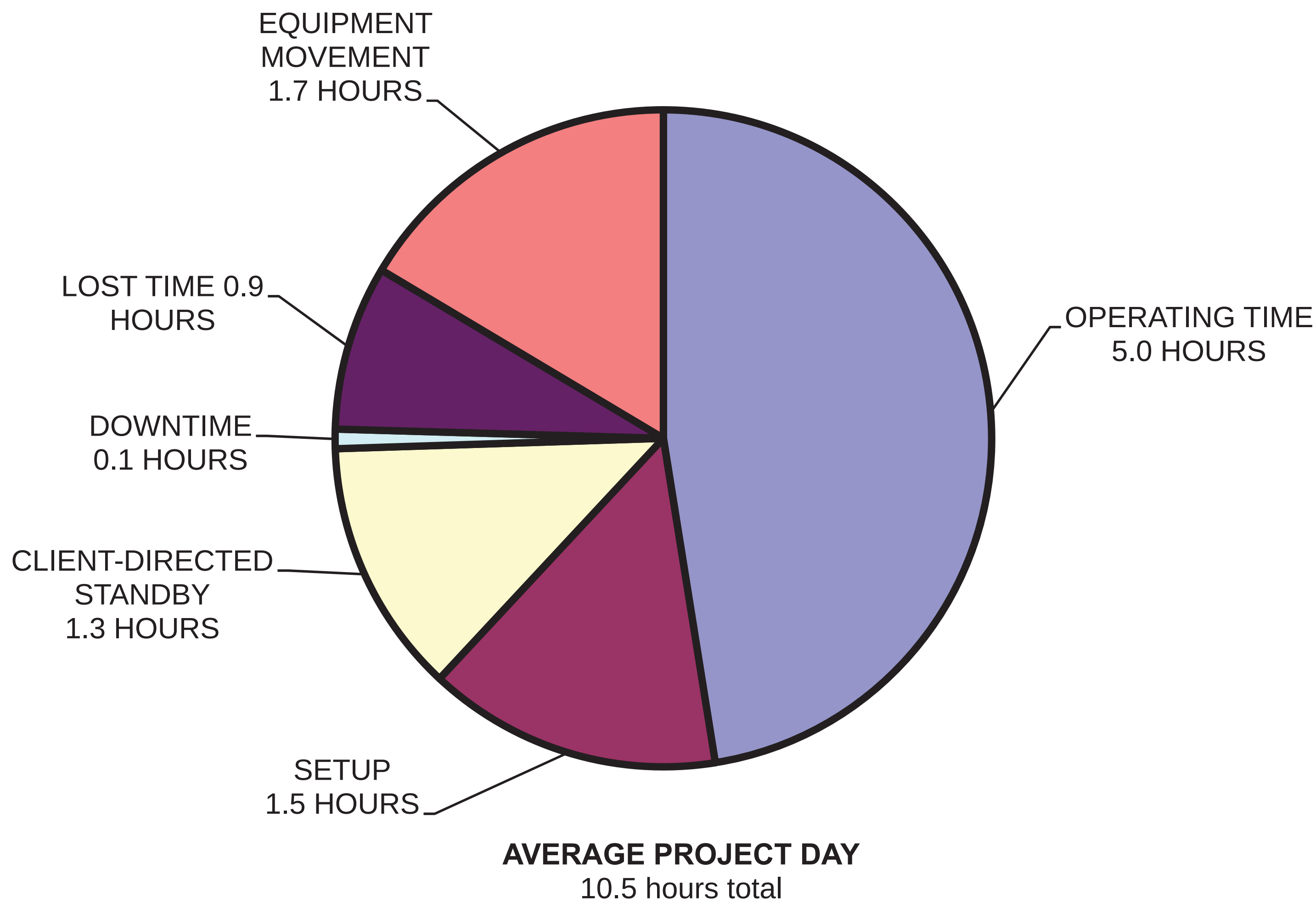
Figure 4-3



Clam Vision® Cumulative Area Dredged over Five-Day Pilot Study

Lower Passaic River Restoration Project

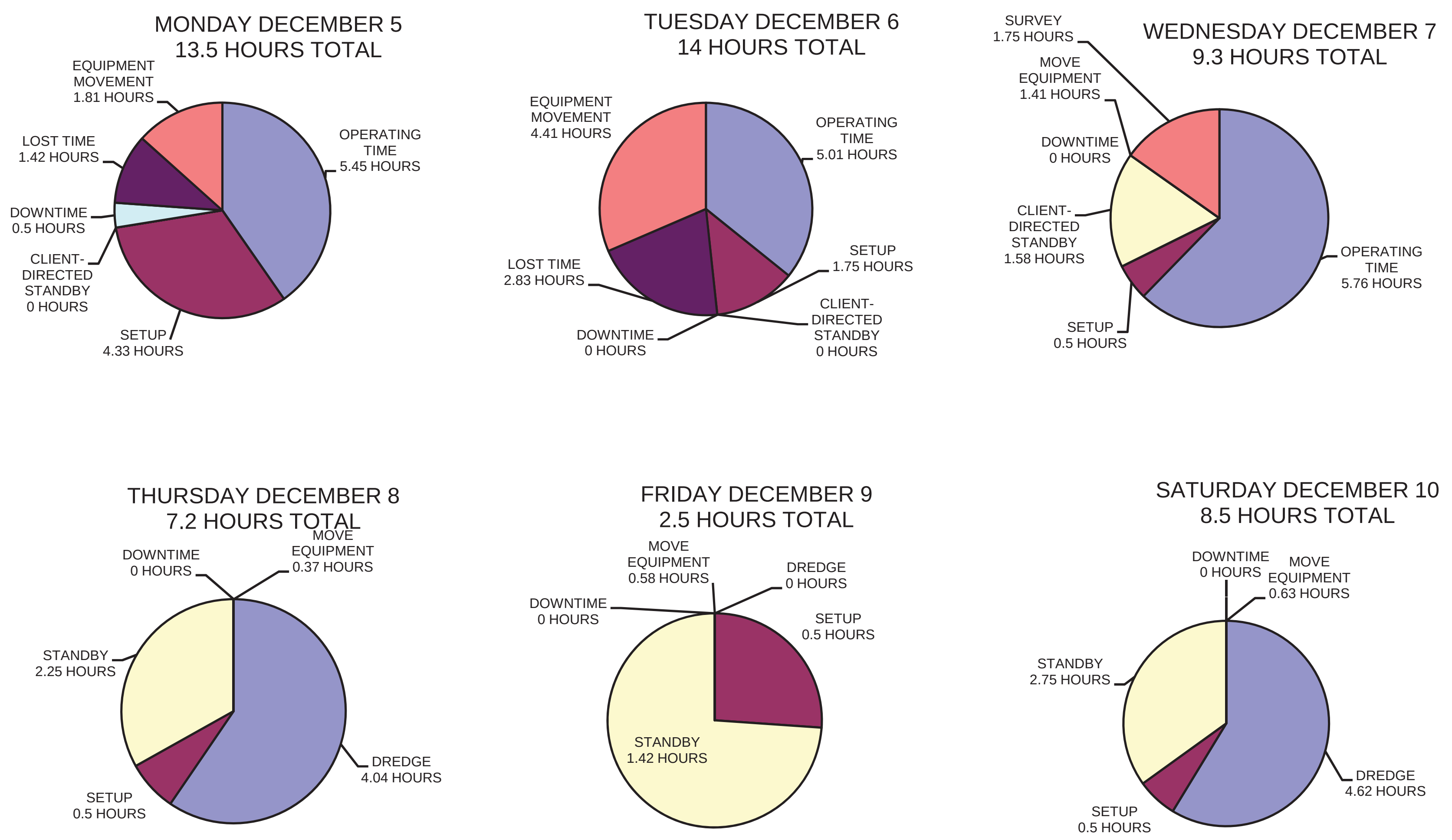
Figure 5-1



Breakdown of Average Work Day

Lower Passaic River Restoration Project

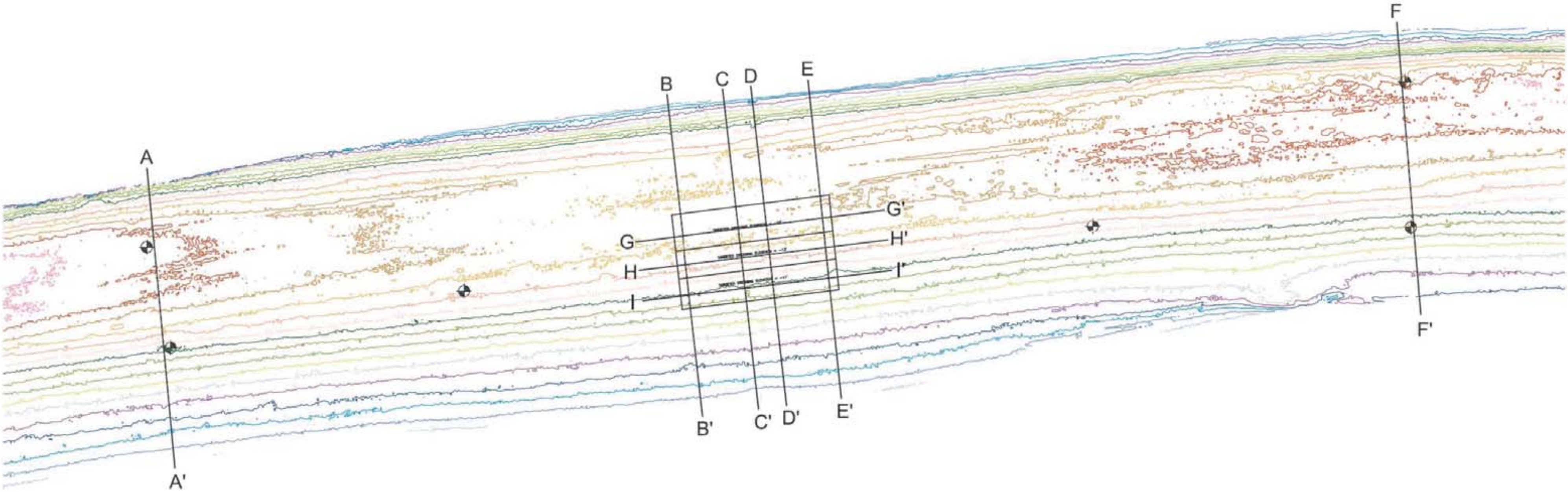
Figure 5-2



Breakdown of Individual Work Days

Lower Passaic River Restoration Project

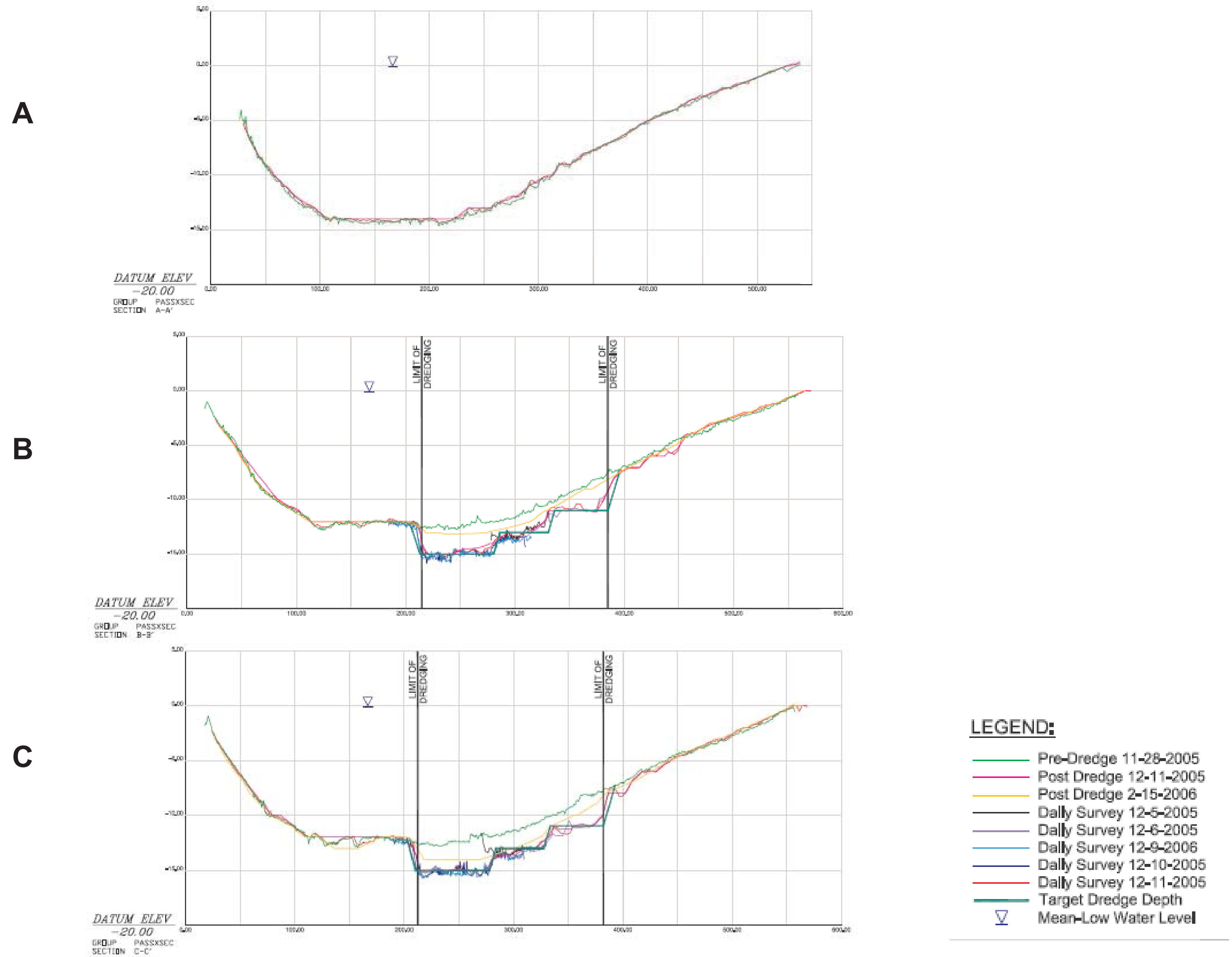
Figure 5-3



Cross-Sections of Dredge Area and River Elevation During Pilot Study

Lower Passaic River Restoration Project

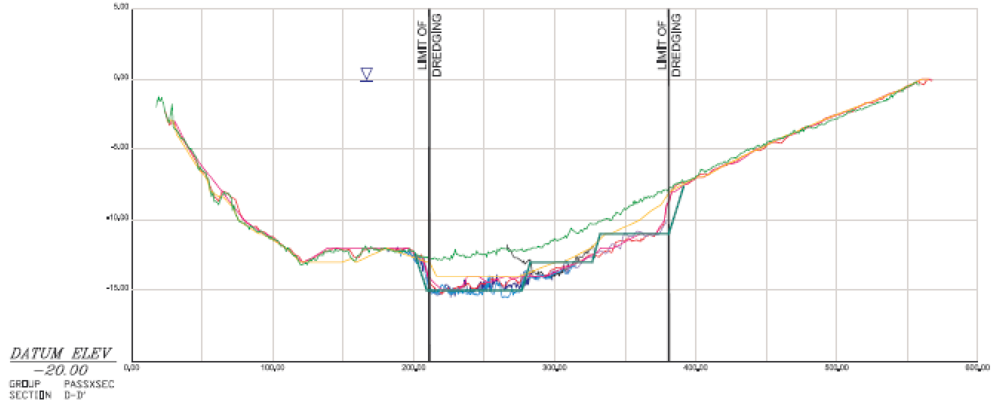
Figure 5-4a



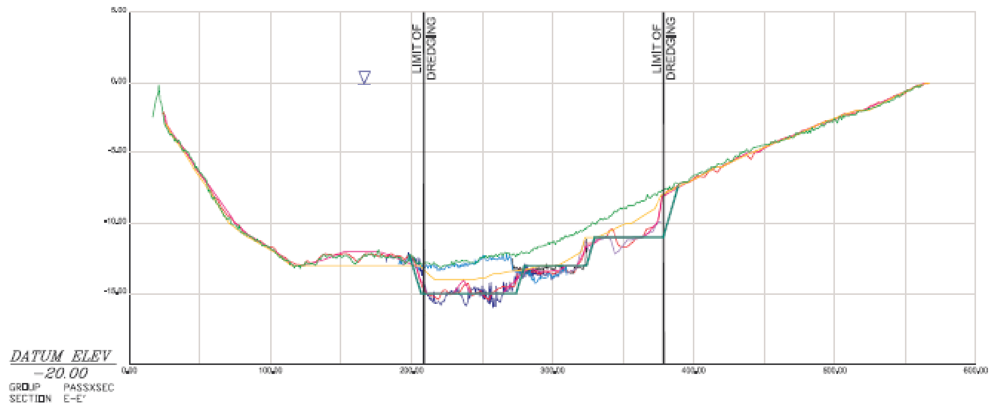
Cross-Sections of Dredge Area and River Elevation During Pilot Study
(Cross Section A-C)
Lower Passaic River Restoration Project

Figure 5-4b

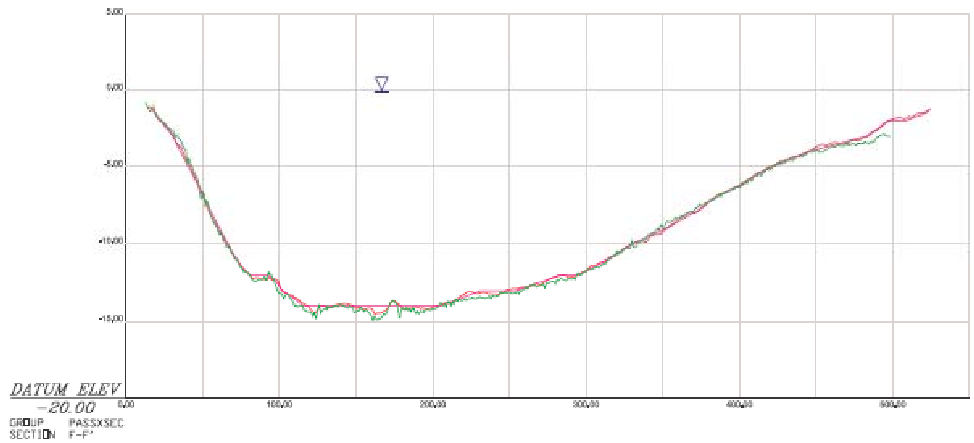
D



E



F



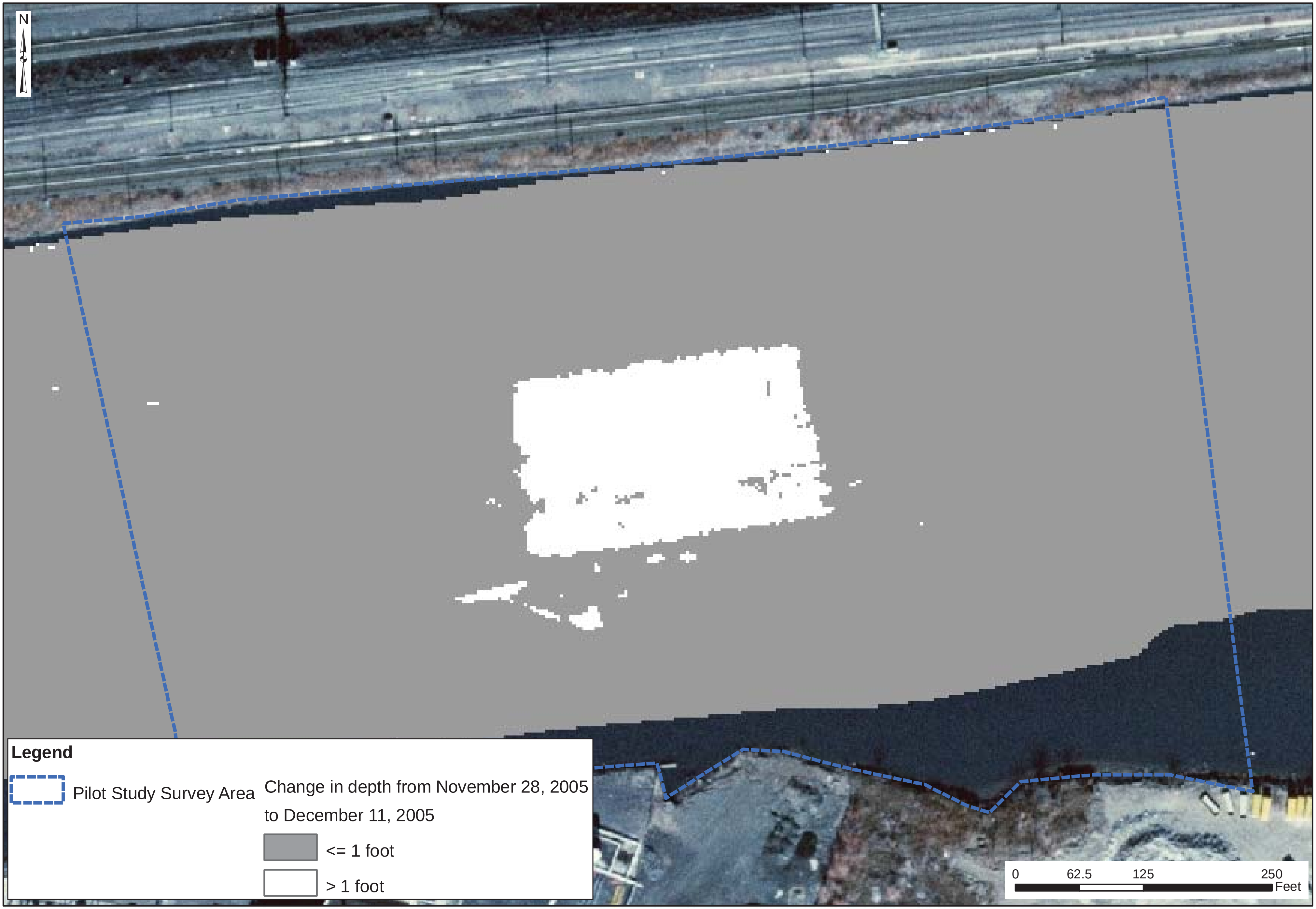
LEGEND:

- Pre-Dredge 11-28-2005
- Post Dredge 12-11-2005
- Post Dredge 2-15-2006
- Daily Survey 12-5-2005
- Daily Survey 12-6-2005
- Daily Survey 12-9-2006
- Daily Survey 12-10-2005
- Daily Survey 12-11-2005
- Target Dredge Depth
- ∇ Mean-Low Water Level

US Army Corps of Engineers

Cross-Sections of Dredge Area and River Elevation During Pilot Study
(Cross Section D-F)
Lower Passaic River Restoration Project

Figure 5-4c

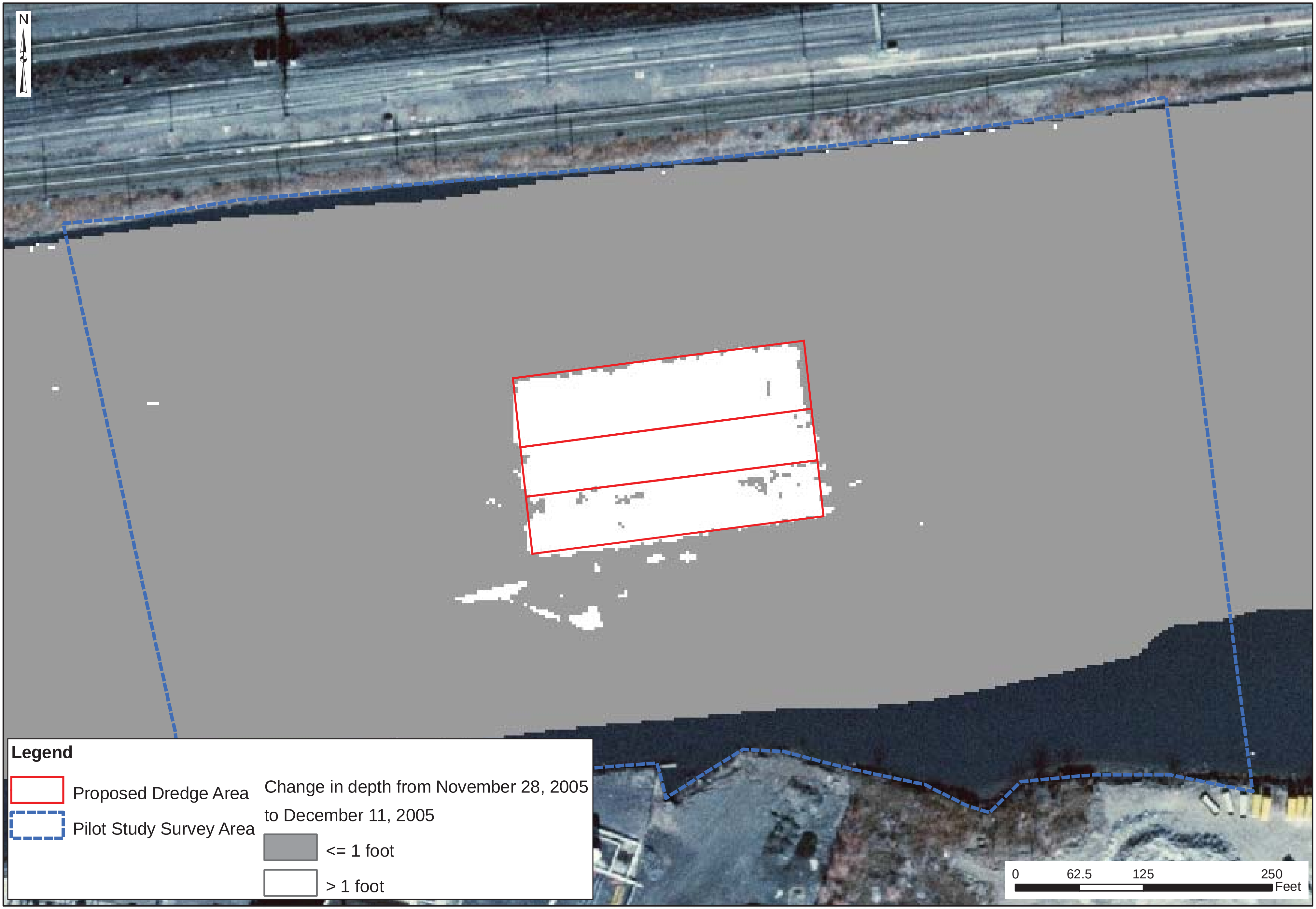


Comparison of Pre-Dredge and Post-Dredge Bathymetric Surveys
Lower Passaic River Restoration Project

Data Source:
1) Aerials, NJGIN, 2002
2) Bathymetry, Rogers Surveying, Inc., 2005

Figure 5-5a

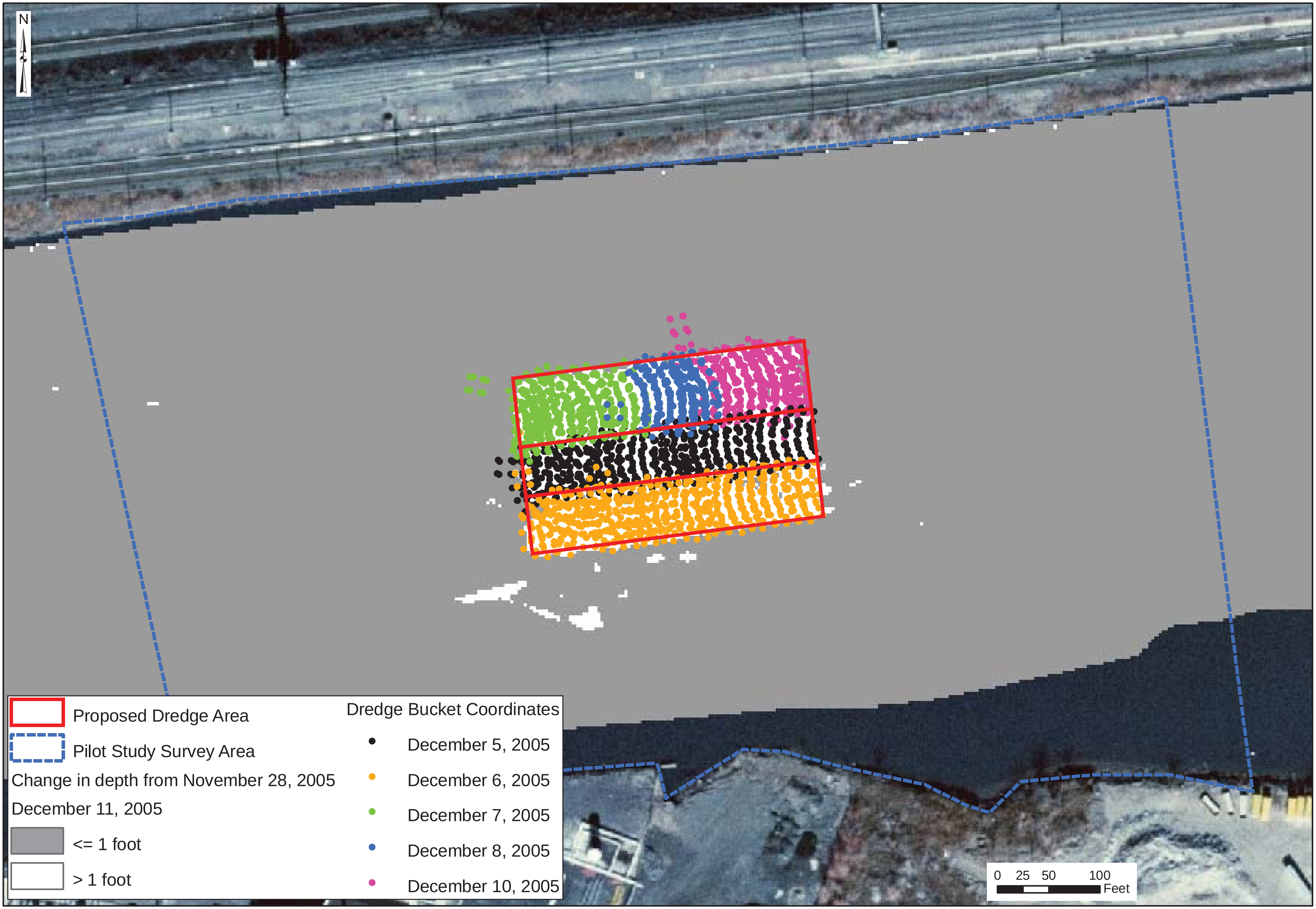
S:\Projects\PASSAIC\MapDocuments\4553001-CERCLA\DredgePilot_Pre_Post_BathyComparison.mxd



Comparison of Pre-Dredge and Post-Dredge Bathymetric Surveys
Lower Passaic River Restoration Project

Data Source:
1) Aerials, NJGIN, 2002
2) Bathymetry, Rogers Surveying, Inc., 2005

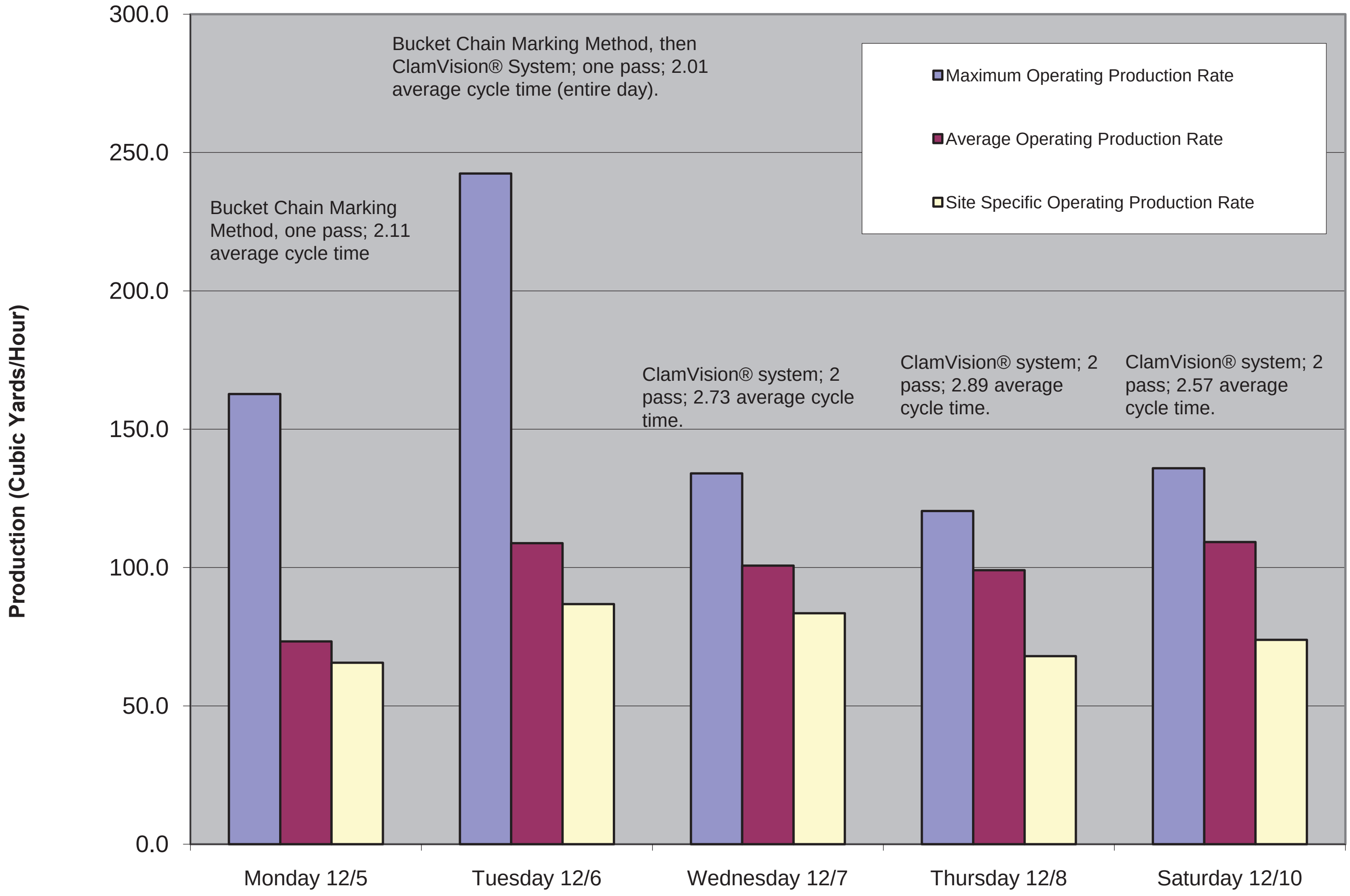
Figure 5-5b



Daily ClamVision Bucket Coordinates Overlay
with Pre-Dredge and Post-Dredge Bathymetric Comparison
Lower Passaic River Restoration Project

Data Source:
1) Aerials, NJGIN 2002
2) Bathymetry, Rogers Surveying, Inc., 2005

Figure 5-6



Productivity Rates During Pilot Study

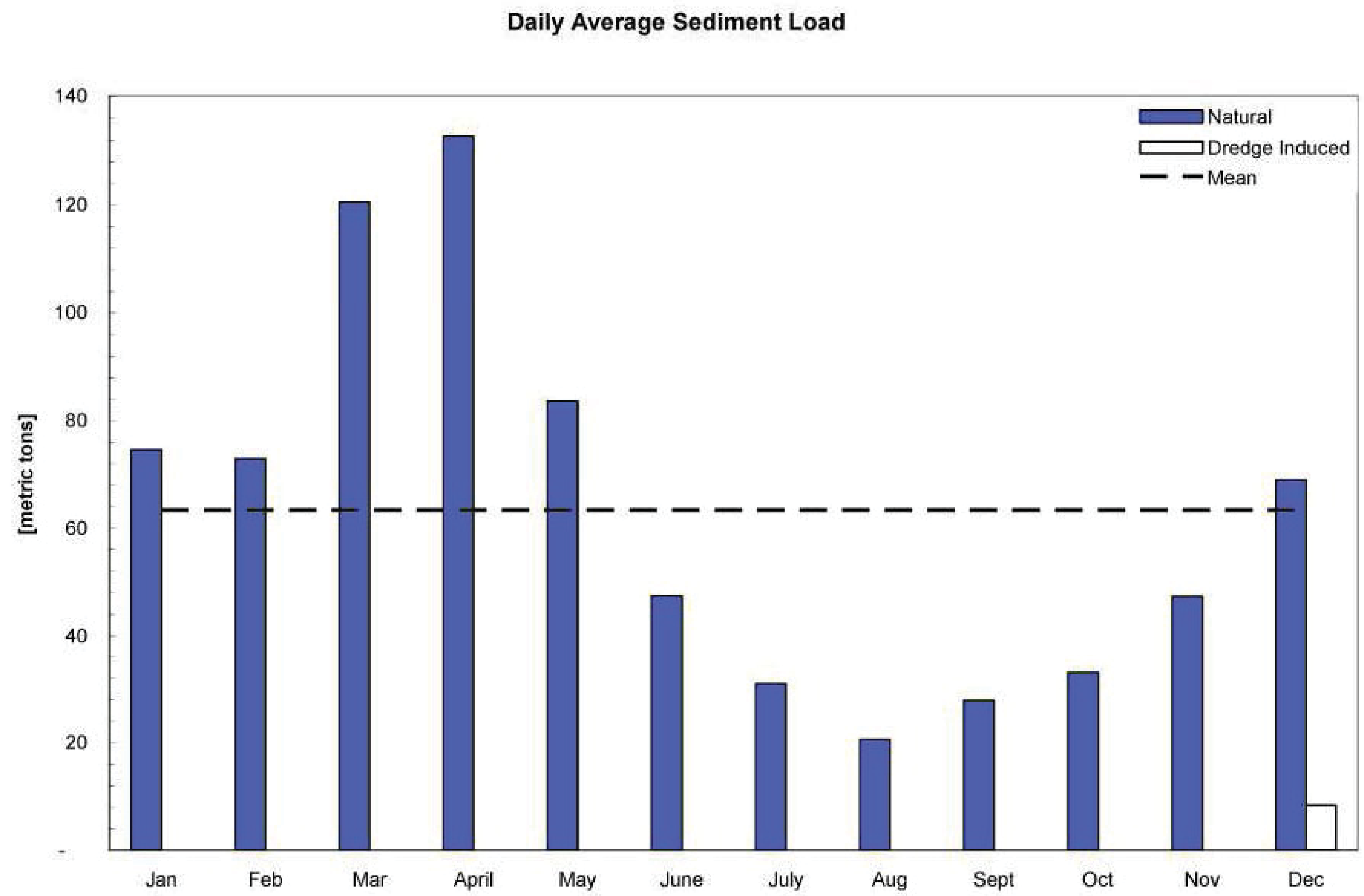
Lower Passaic River Restoration Project

Figure 5-7

Aerial Photograph of Pilot Study Area
Showing Mooring Locations

Lower Passaic River Restoration Project

Figure 6-1

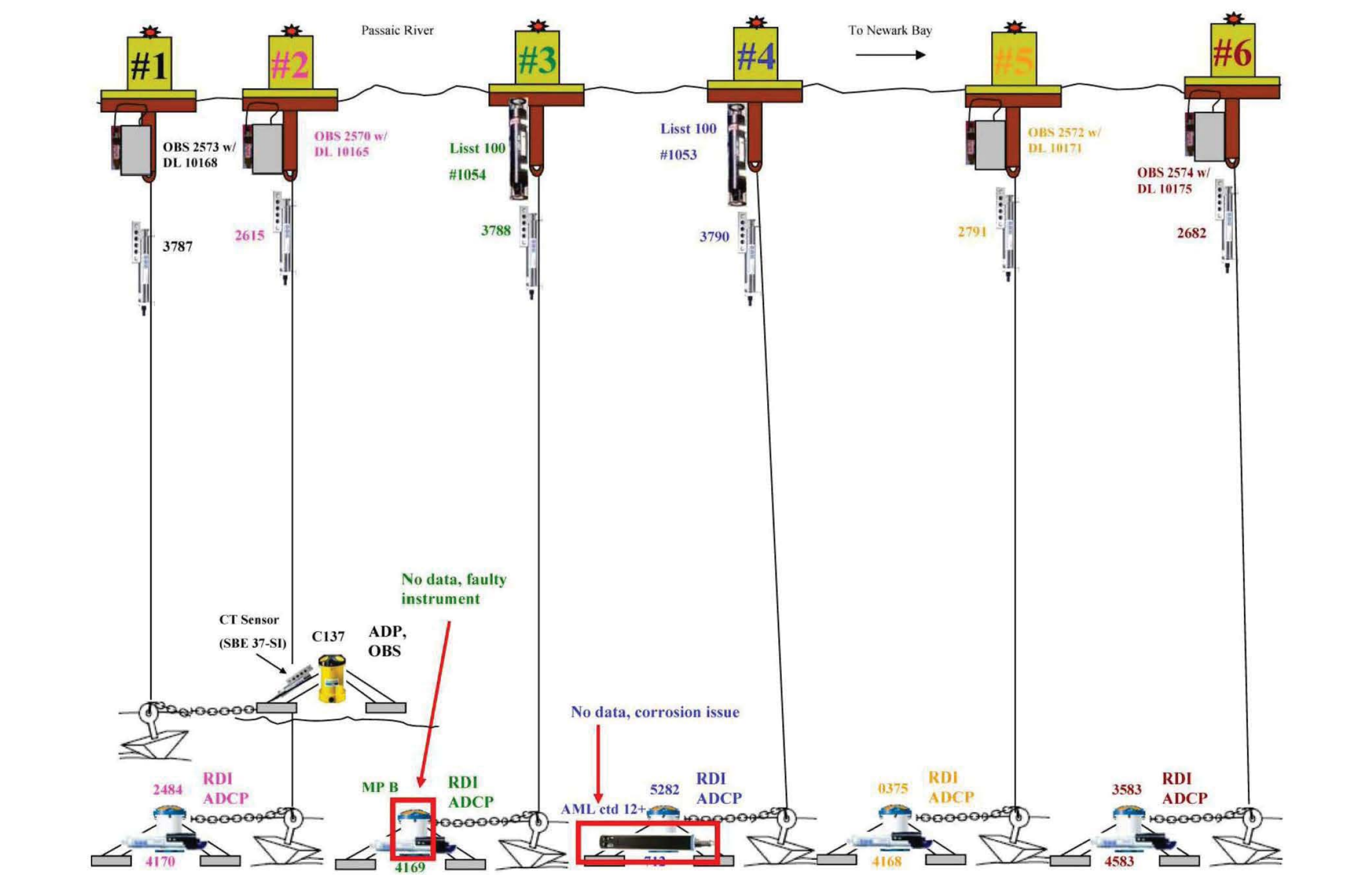


Loads shown are based on modeling results. "Dredge Induced" value plotted (black outlined bar) represents the estimated modeled load of resuspended sediments from the Pilot Study dredging operations.

Average Daily Sediment Load and Model Dredged-Induced Resuspension

Lower Passaic River Restoration Project

Figure 6-2

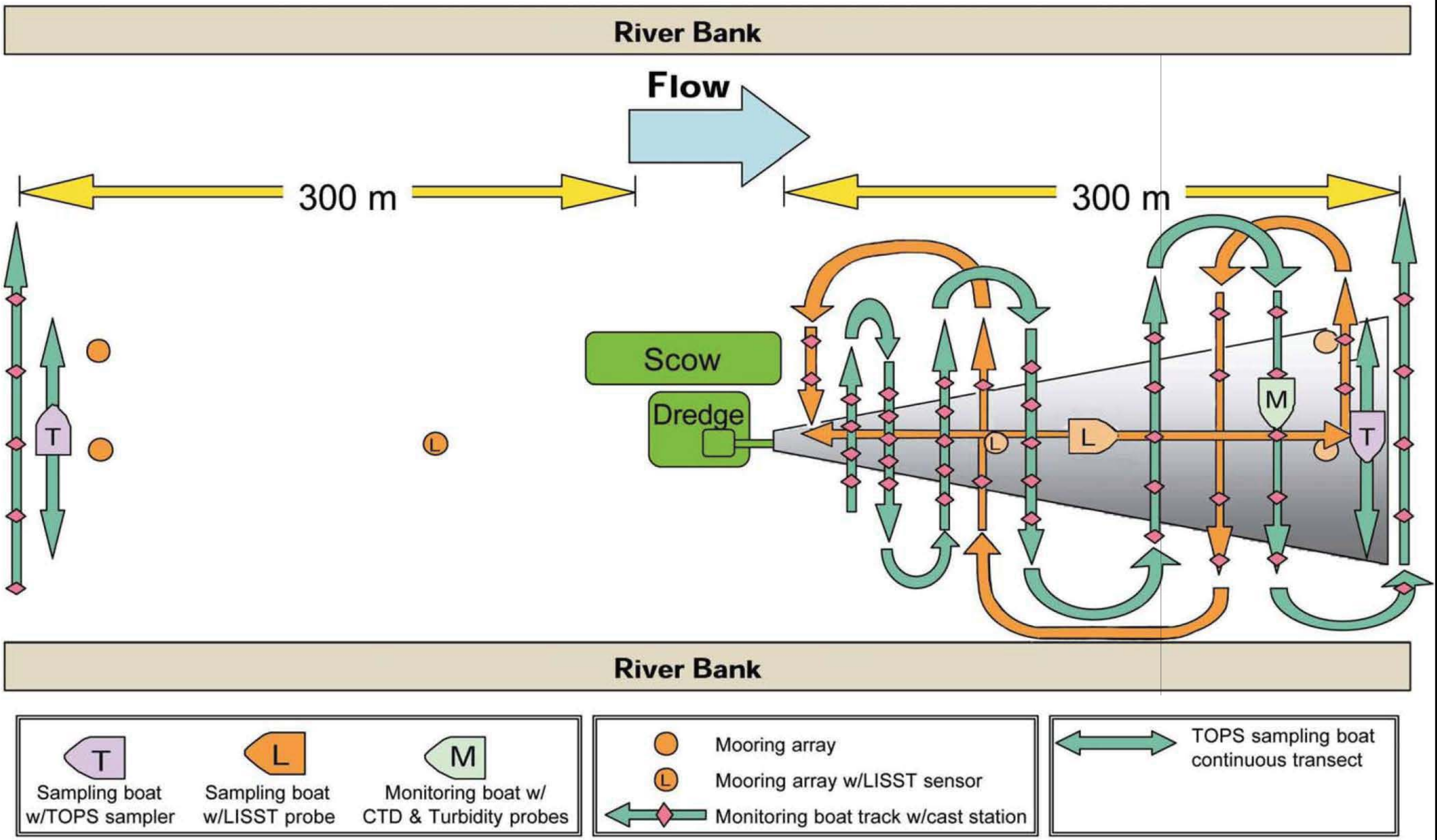


Refer to Table 6-1 for explanation and identification of instruments.

Six Moorings with Instruments, Floats, Anchors, and Tripod Frames

Lower Passaic River Restoration Project

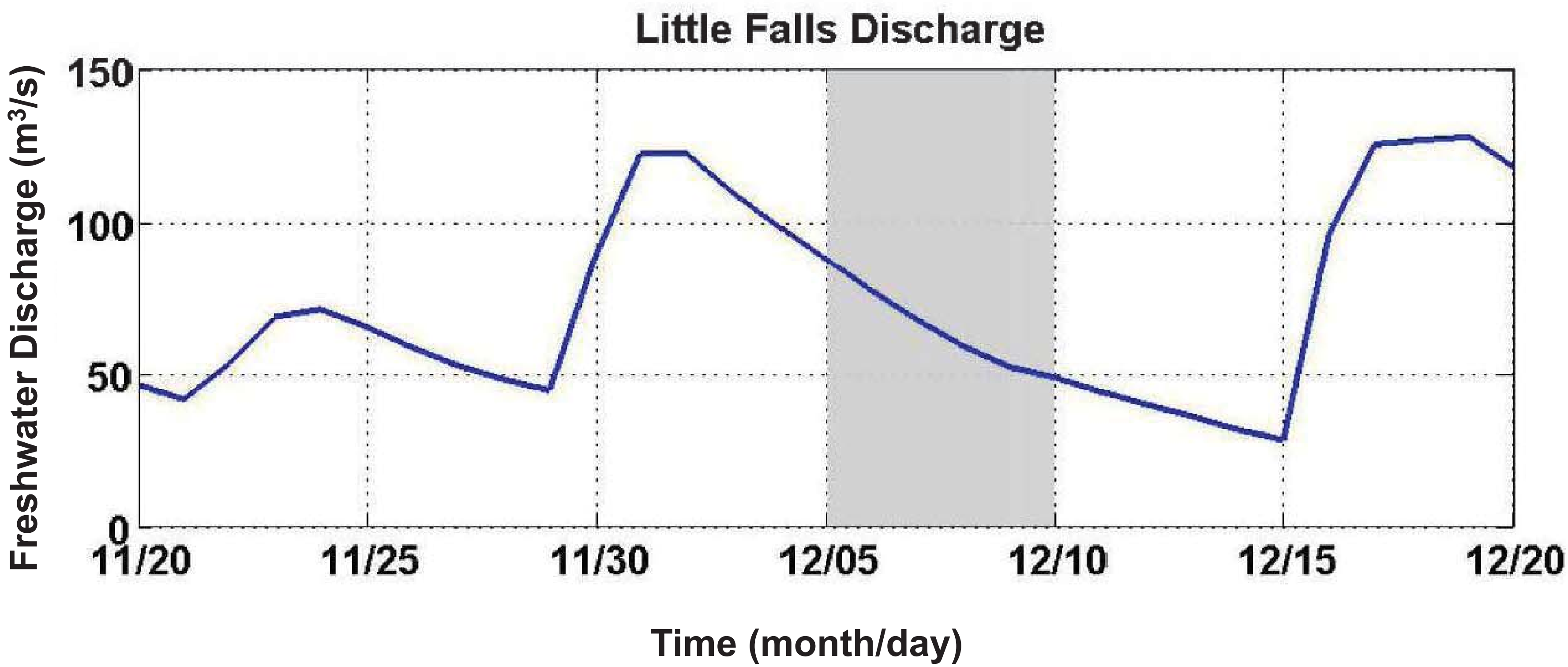
Figure 6-3



Monitoring Mooring Arrangement with Monitoring Boat Tracks

Lower Passaic River Restoration Project

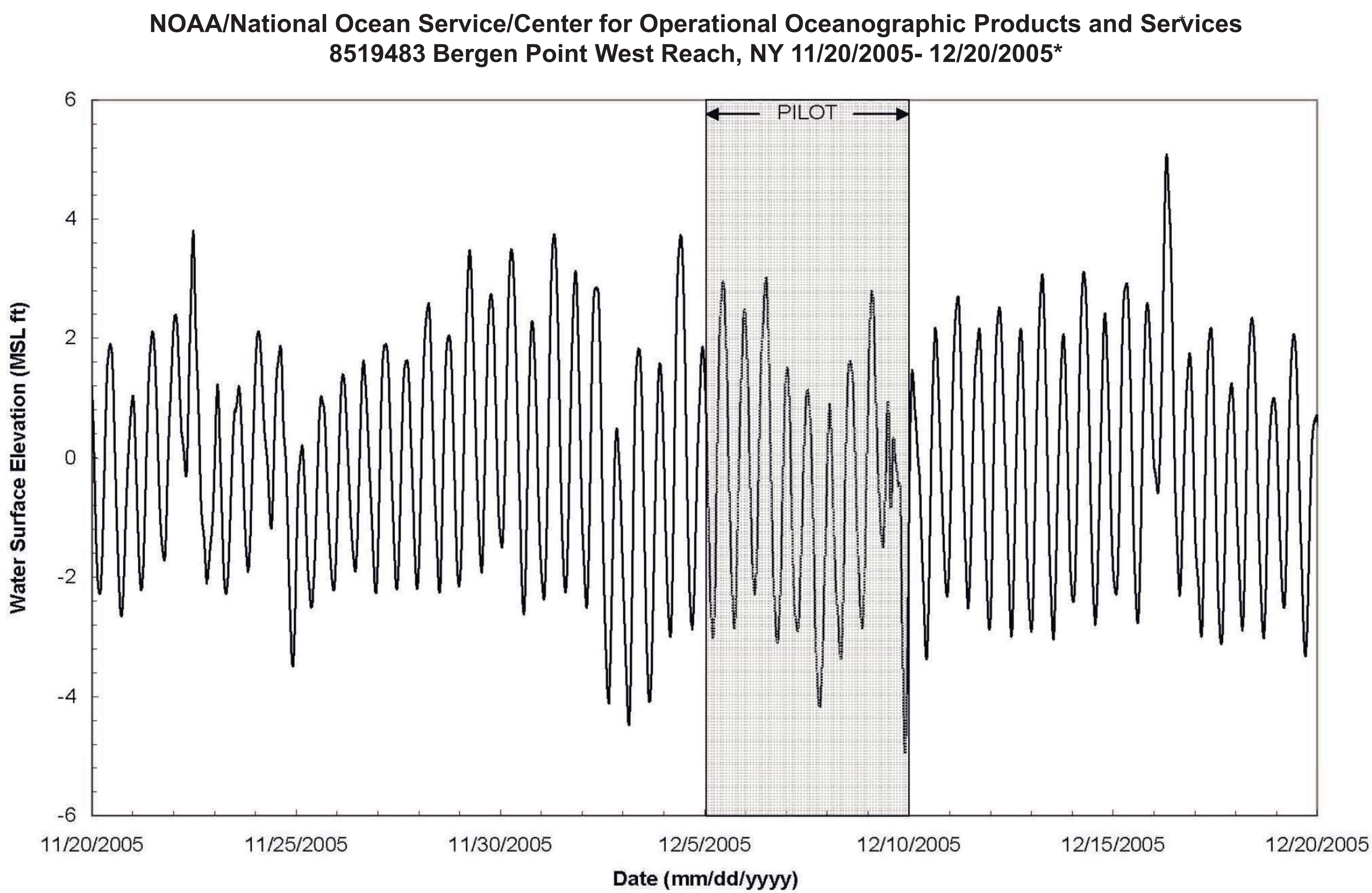
Figure 6-4



Discharge at USGS Gauge in Little Falls, New Jersey from November 20, 2005 to December 20, 2005

Lower Passaic River Restoration Project

Figure 7-1

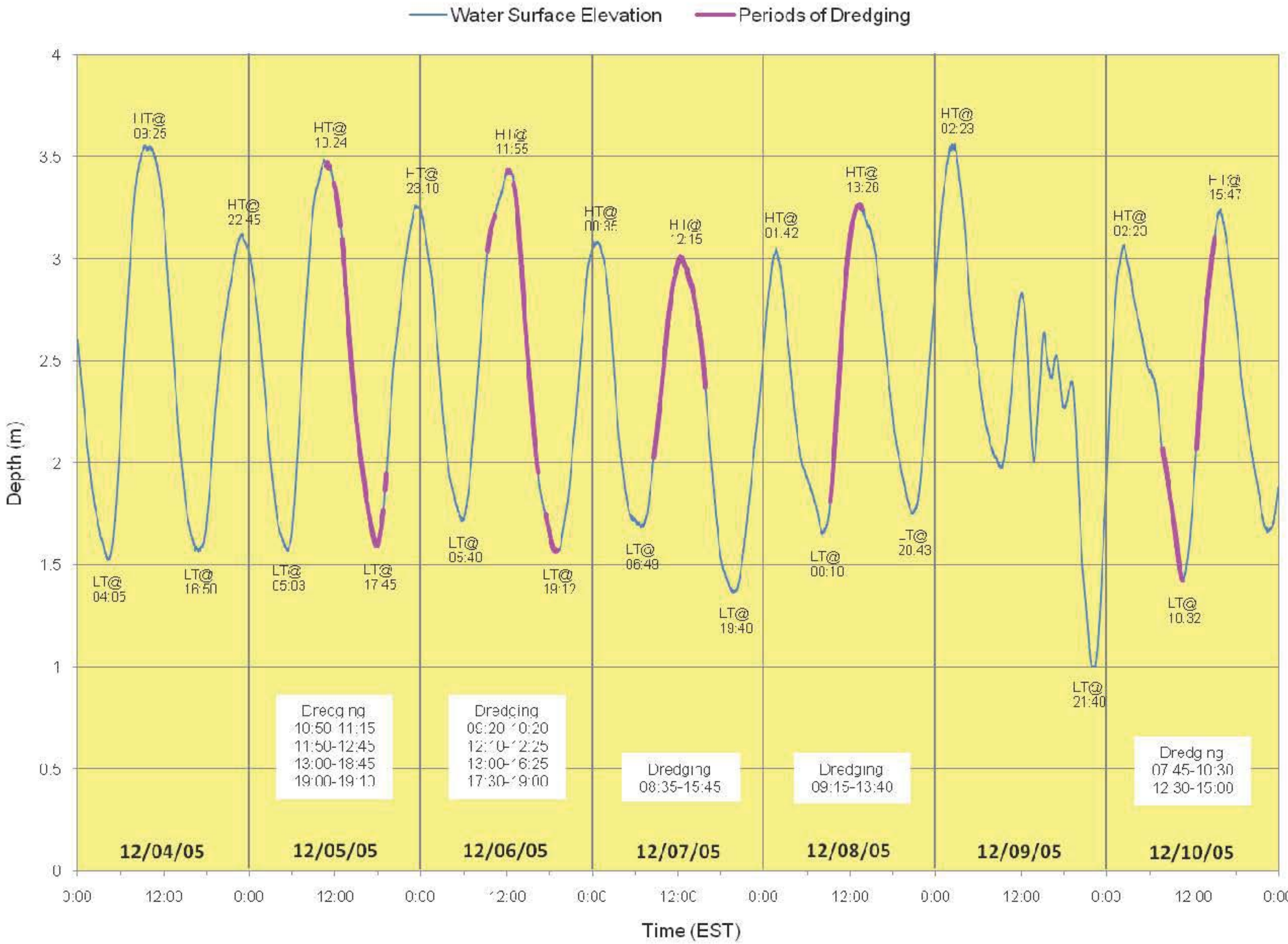


* Closest station to dredge pilot study location.

Sea Level Recorded by NOAA at Bergen Point West Reach, New York

Lower Passaic River Restoration Project

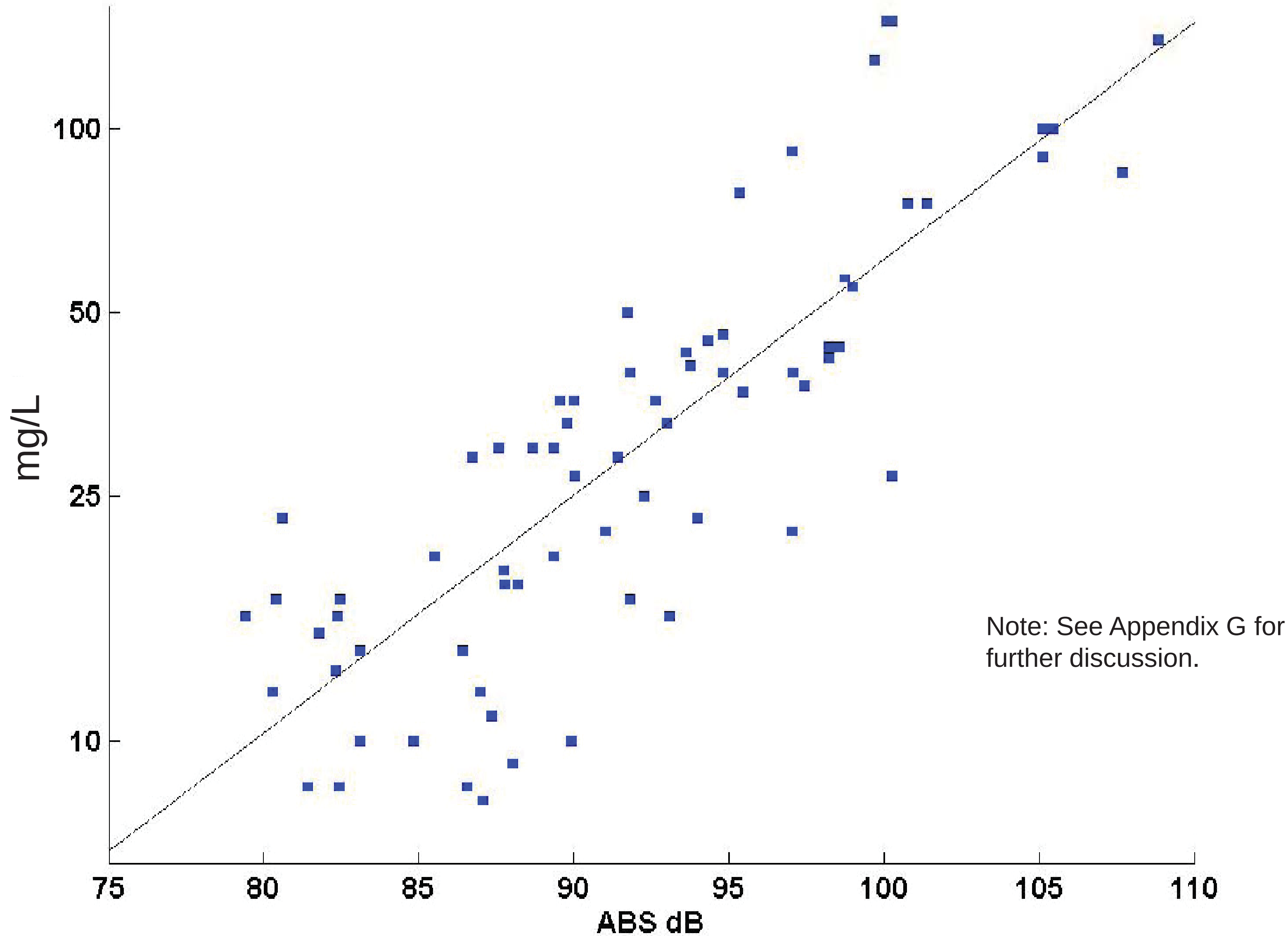
Figure 7-2



Water Surface Elevation Measured at Mooring 2

Lower Passaic River Restoration Project

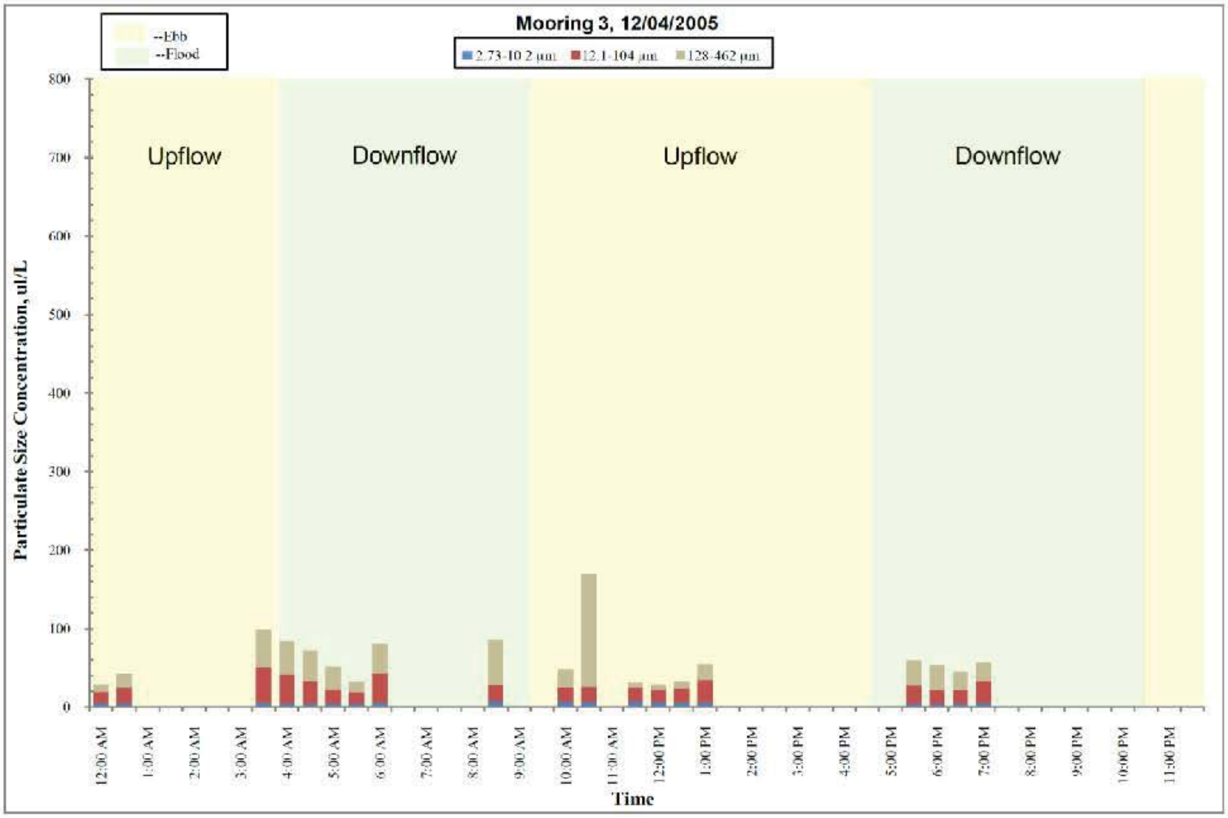
Figure 7-3

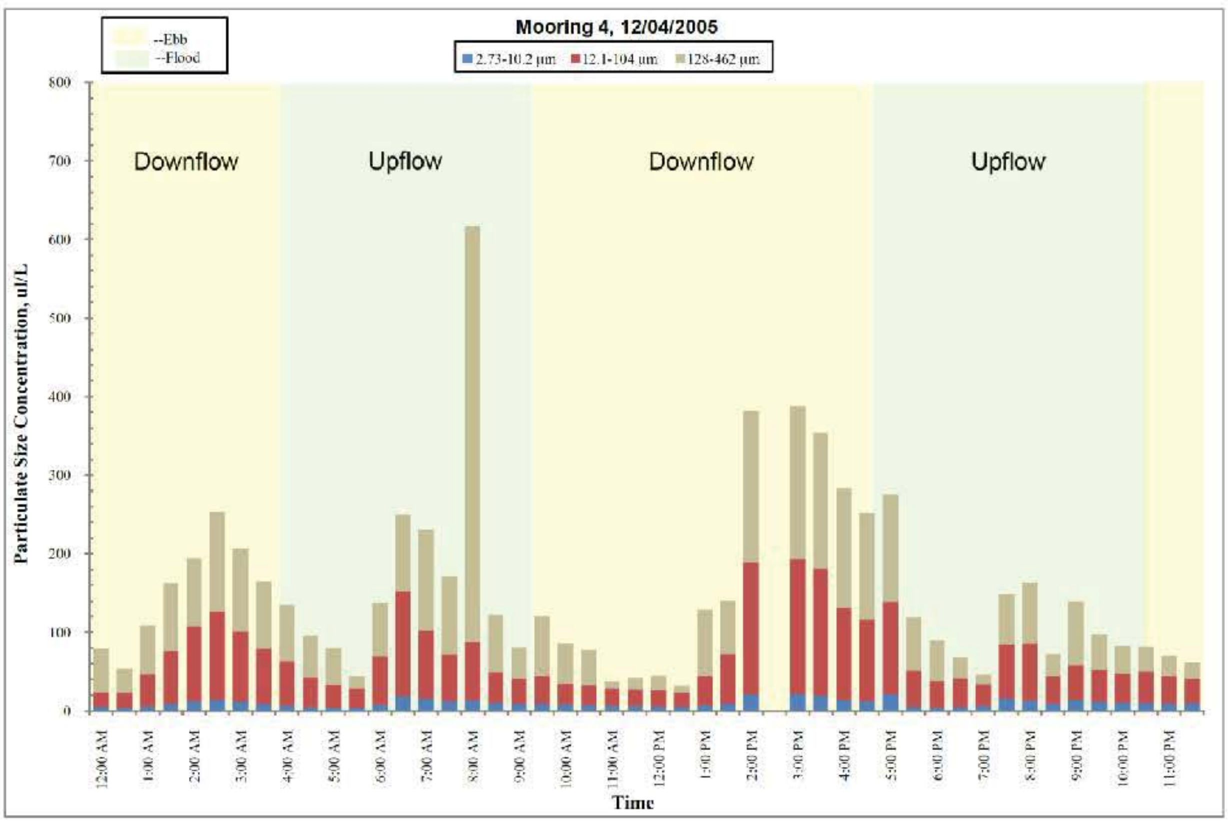


TSS Calibration Plot for the *R/V Caleta* ADCP Measurements

Lower Passaic River Restoration Project

Figure 7-4

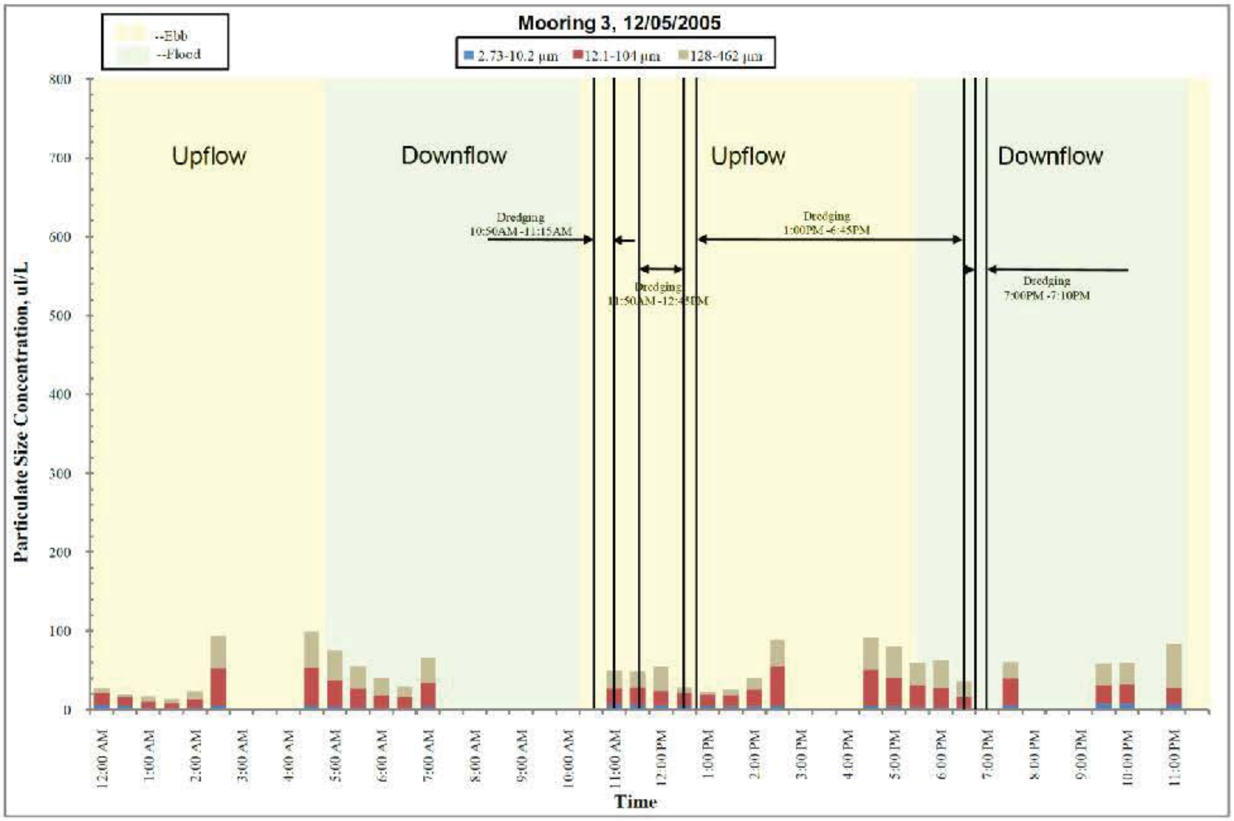


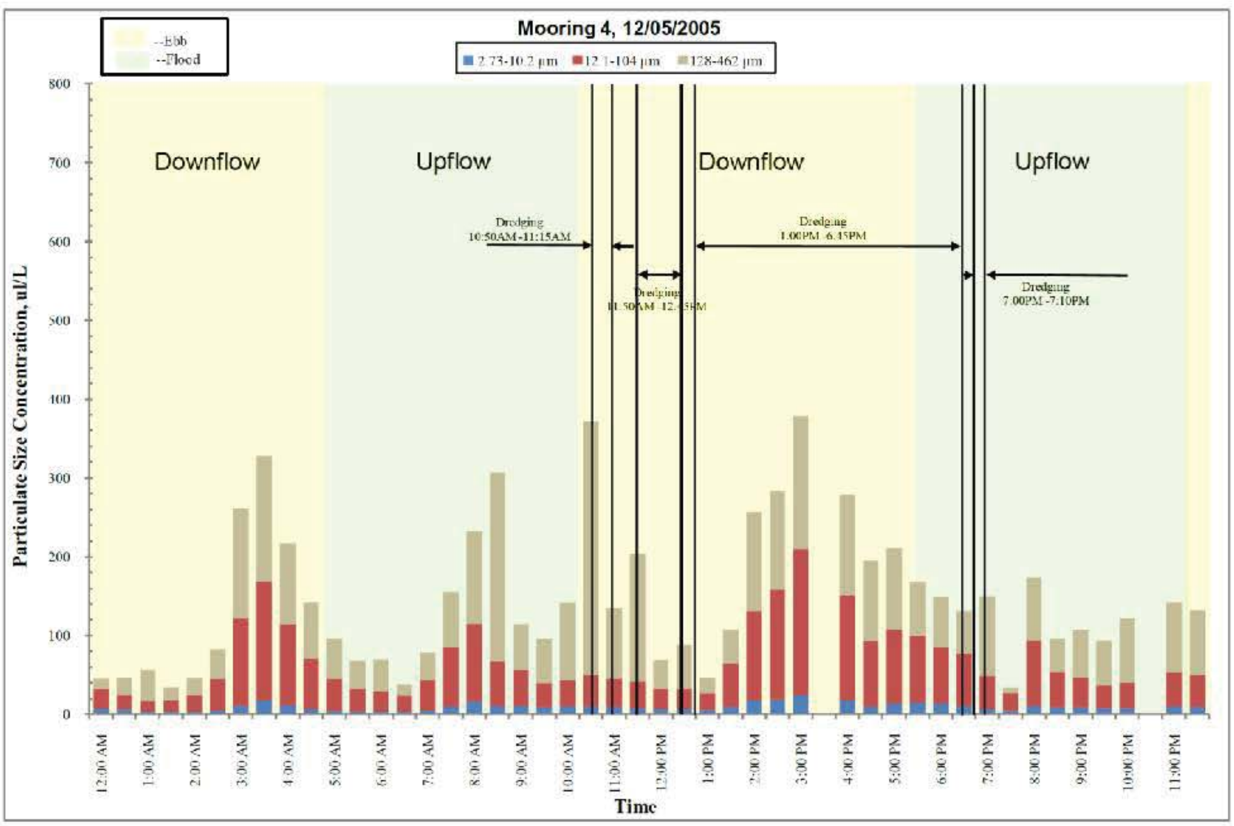


LISST Data for Mooring 3 on December 4, 2005 and Mooring 4 on December 4, 2005

Lower Passaic River Restoration Project

Figure 7-5

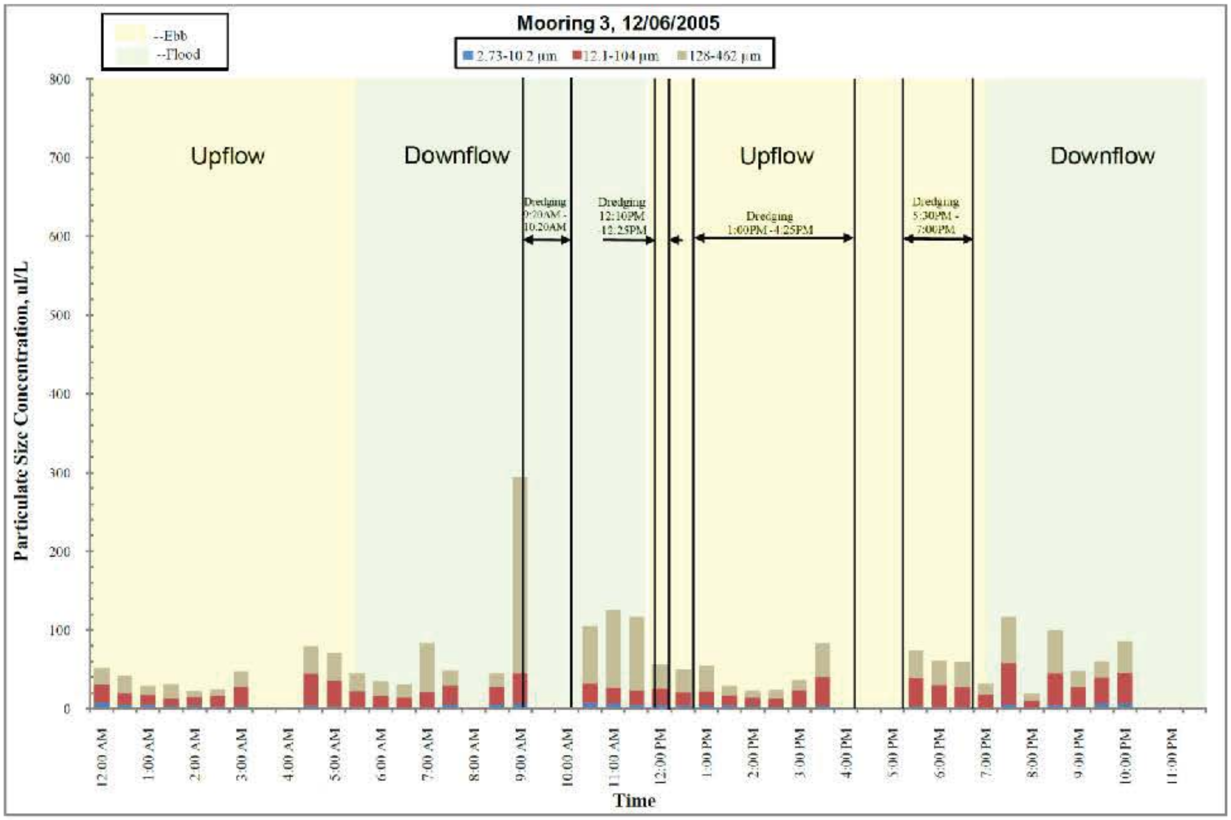


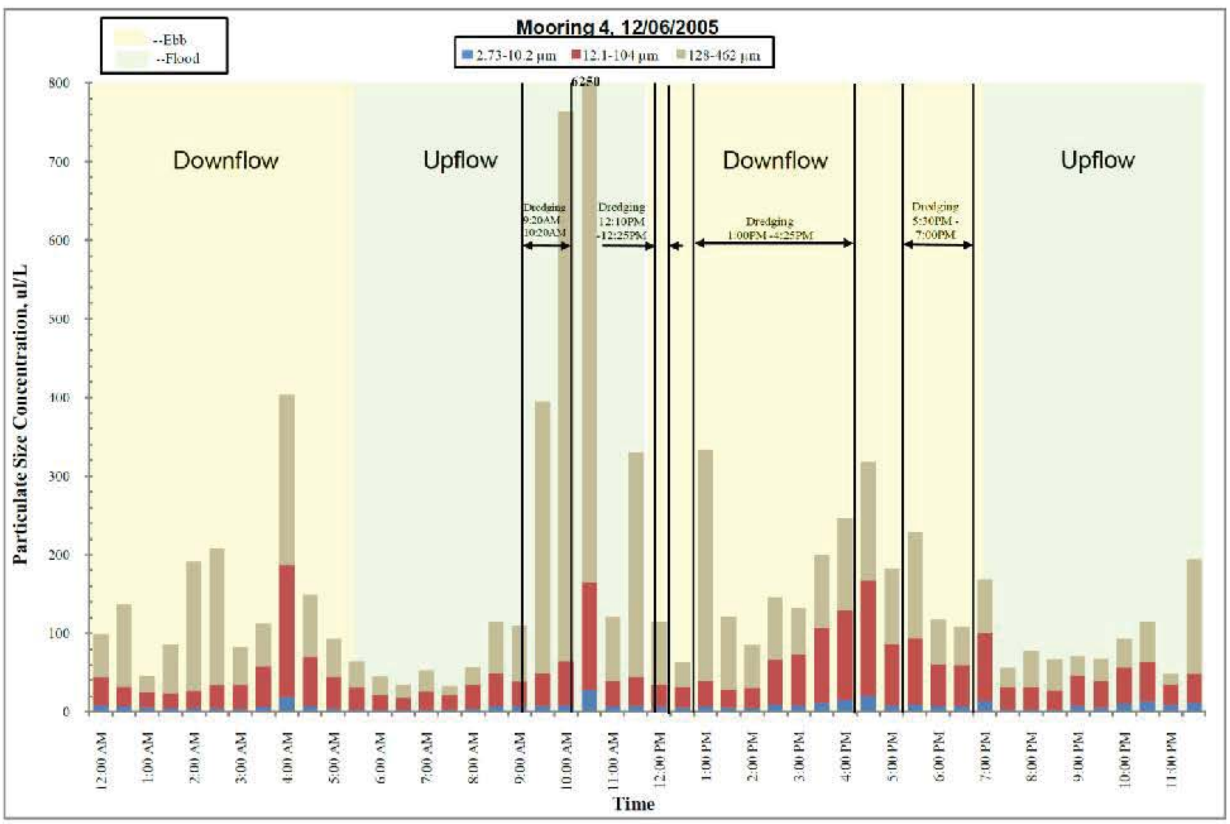


LISST Data for Mooring 3 on December 5, 2005 and Moorings 4 on December 5, 2005

Lower Passaic River Restoration Project

Figure 7-6

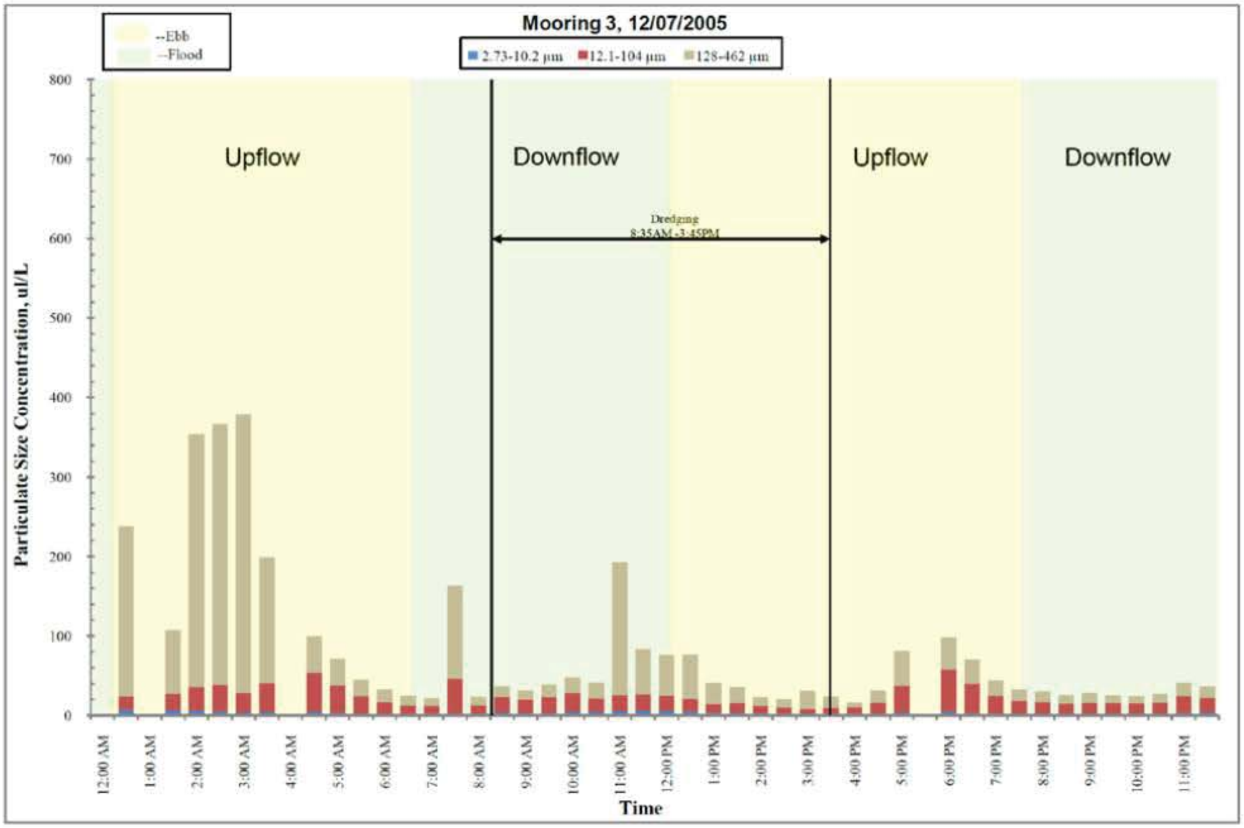


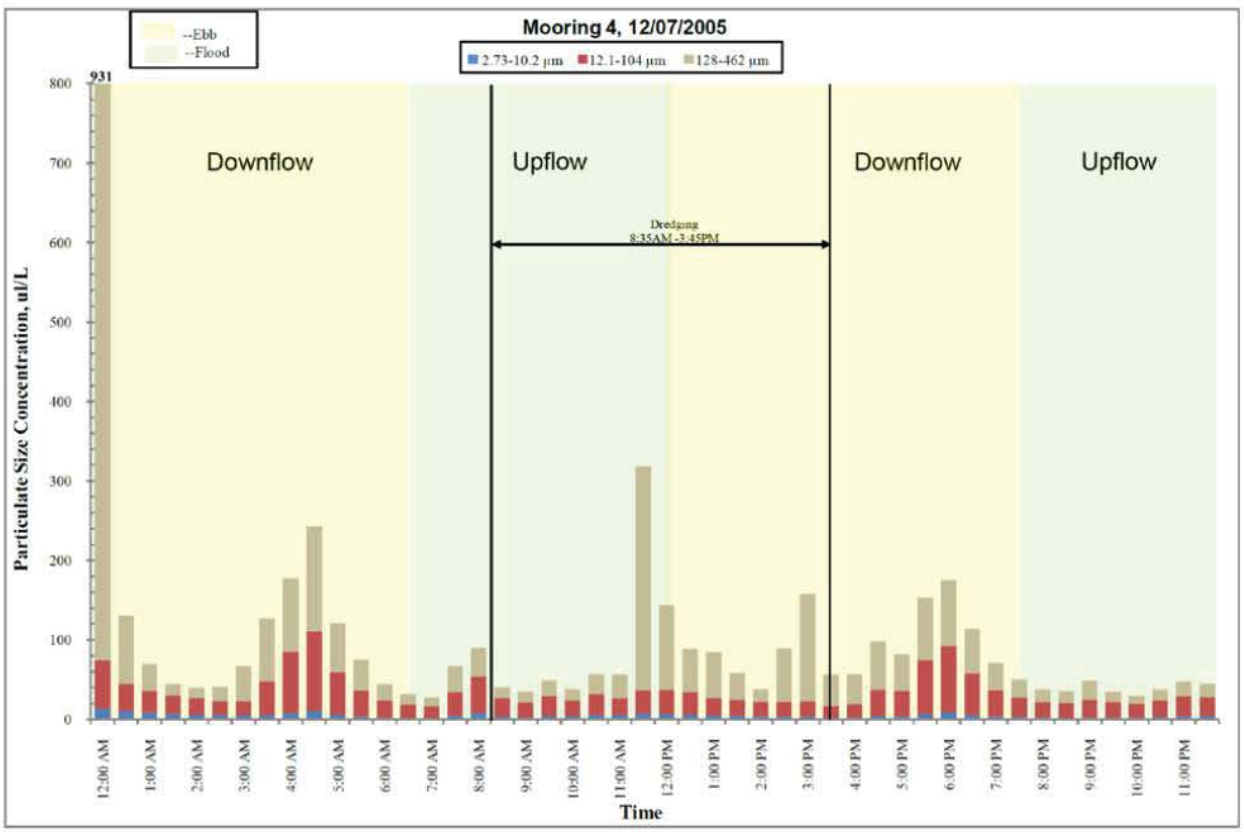


LISST Data for Mooring 3 on December 6, 2005 and Moorings 4 on December 6, 2005

Lower Passaic River Restoration Project

Figure 7-7

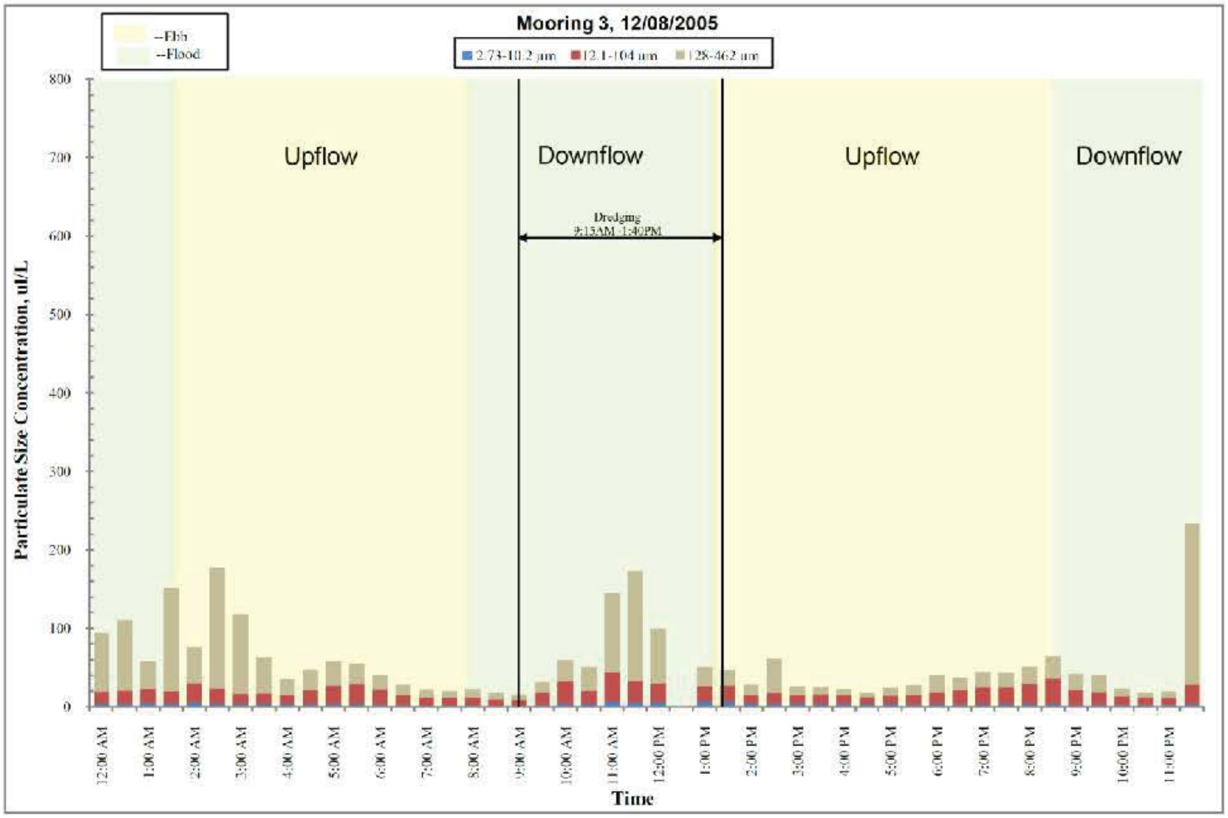


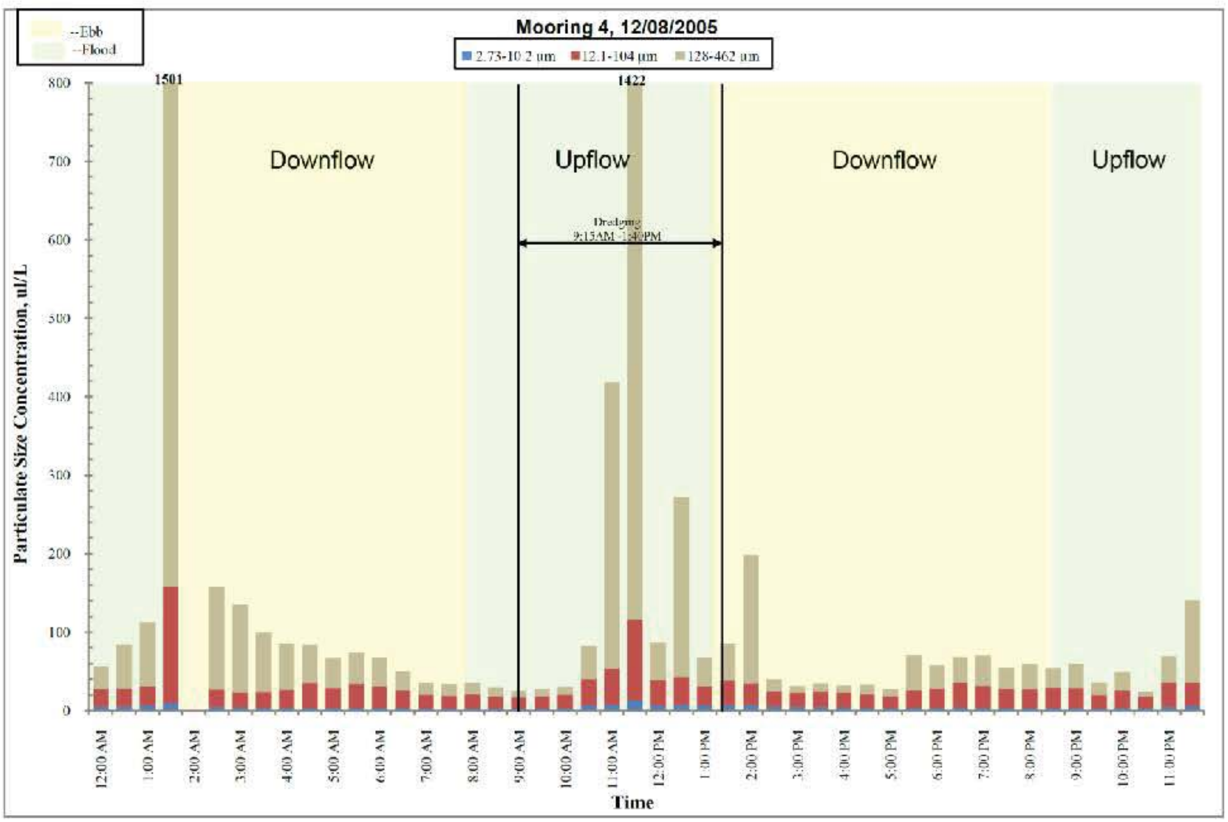


LISST Data for Mooring 3 on December 7, 2005 and Moorings 4 on December 7, 2005

Lower Passaic River Restoration Project

Figure 7-8

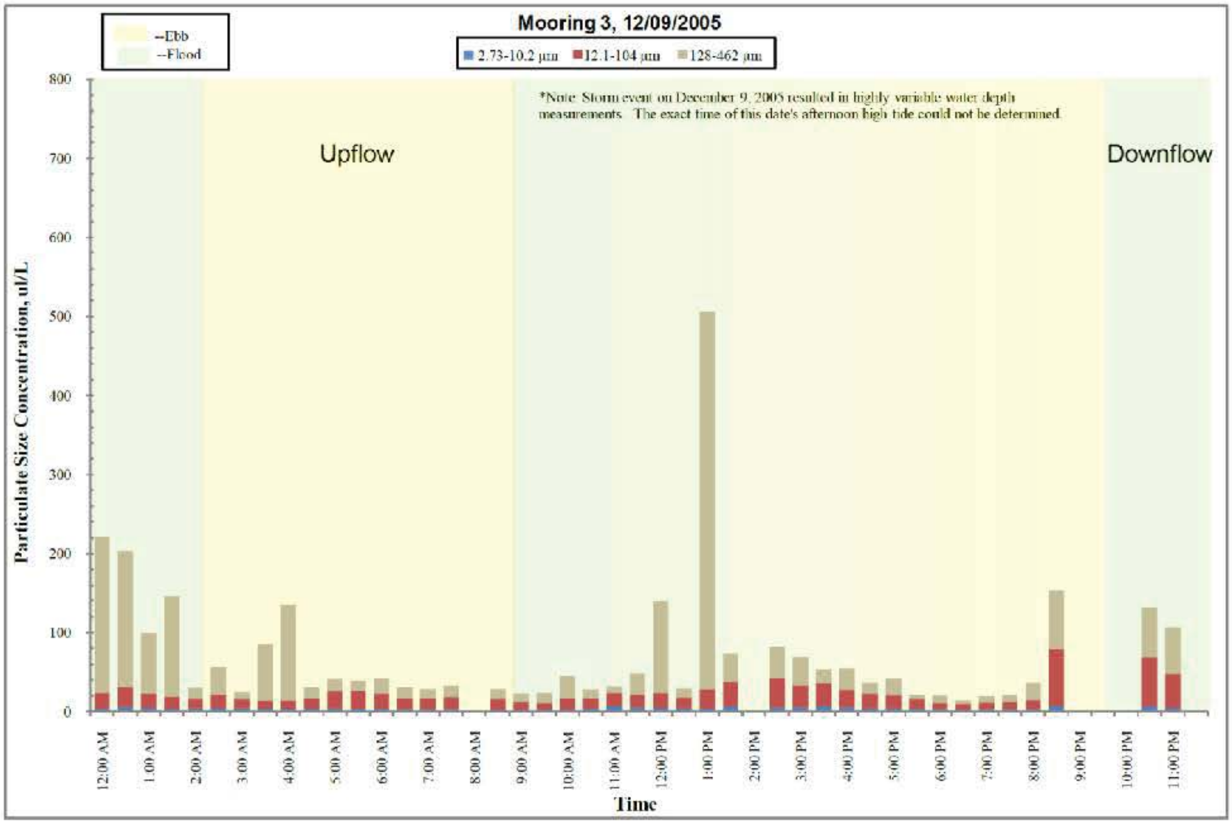


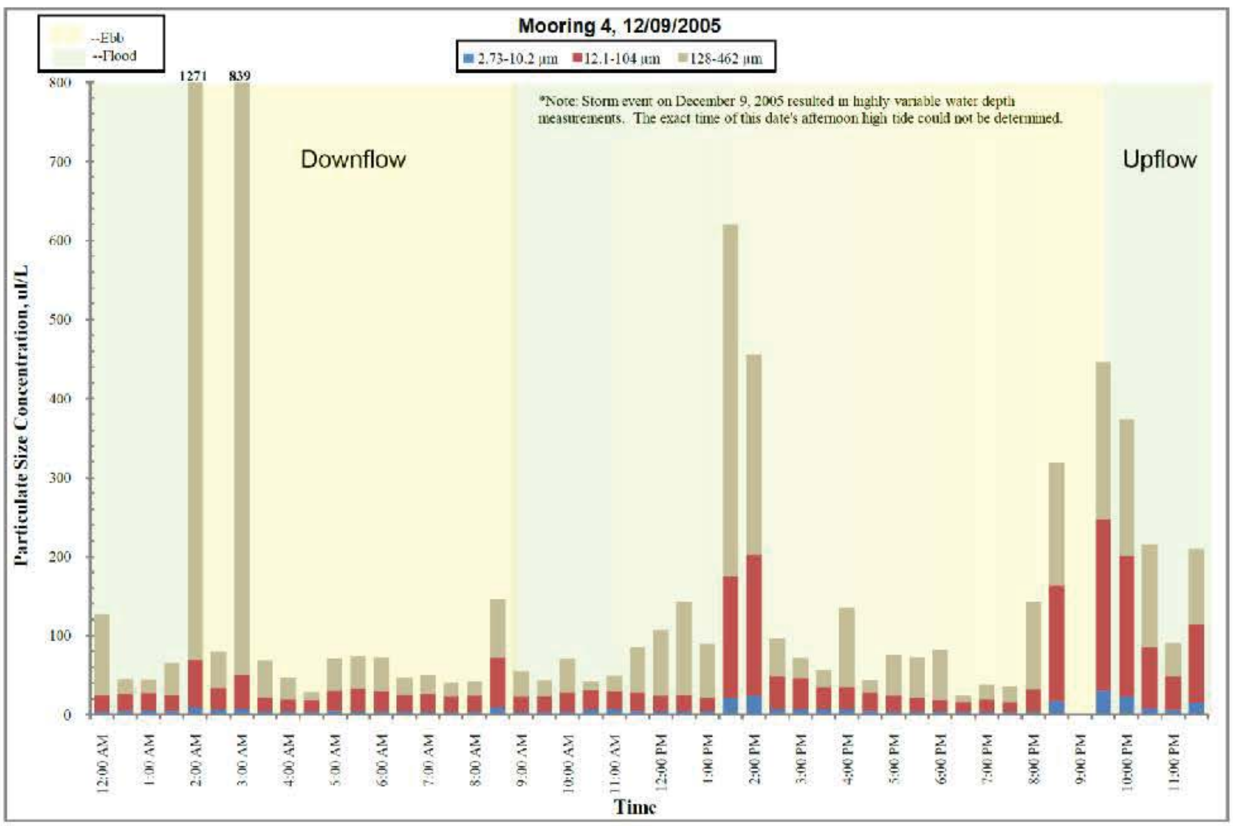


LISST Data for Mooring 3 on December 8, 2005 and Moorings 4 on December 8, 2005

Lower Passaic River Restoration Project

Figure 7-9

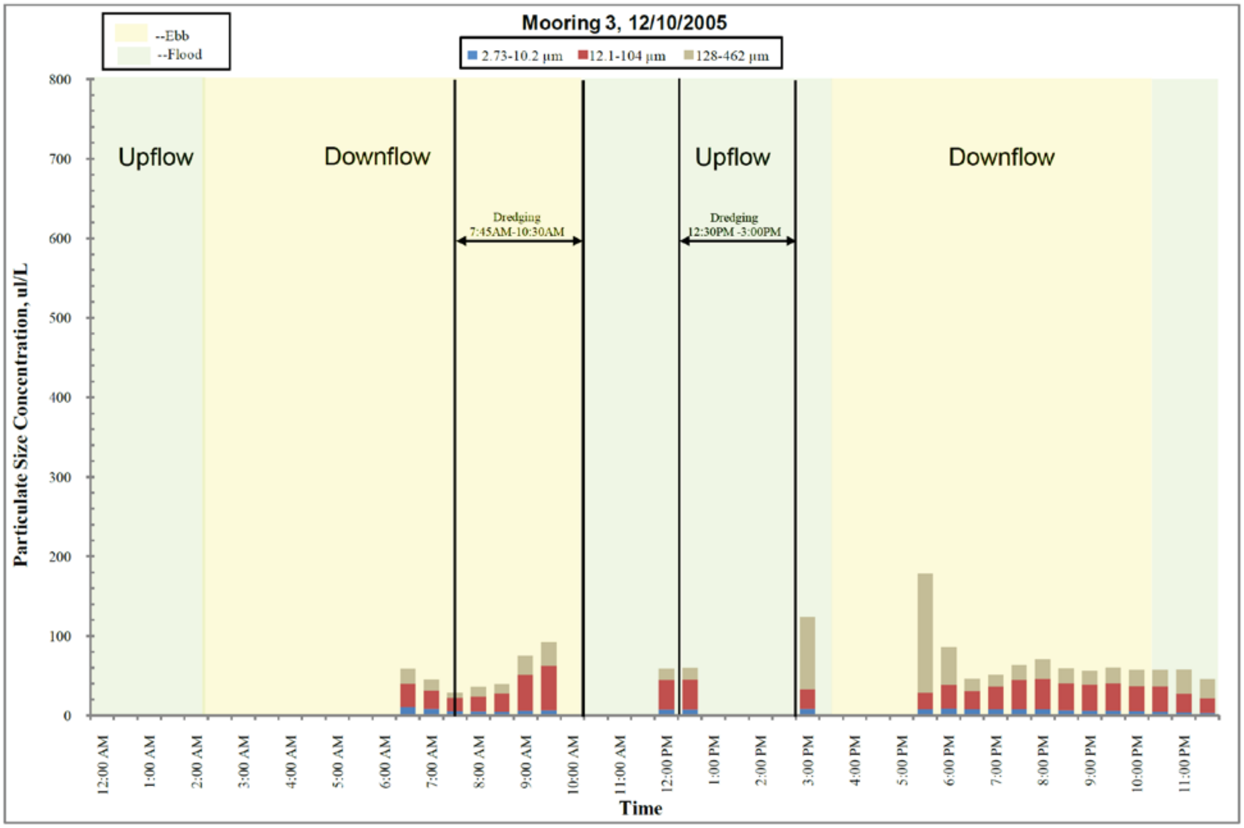


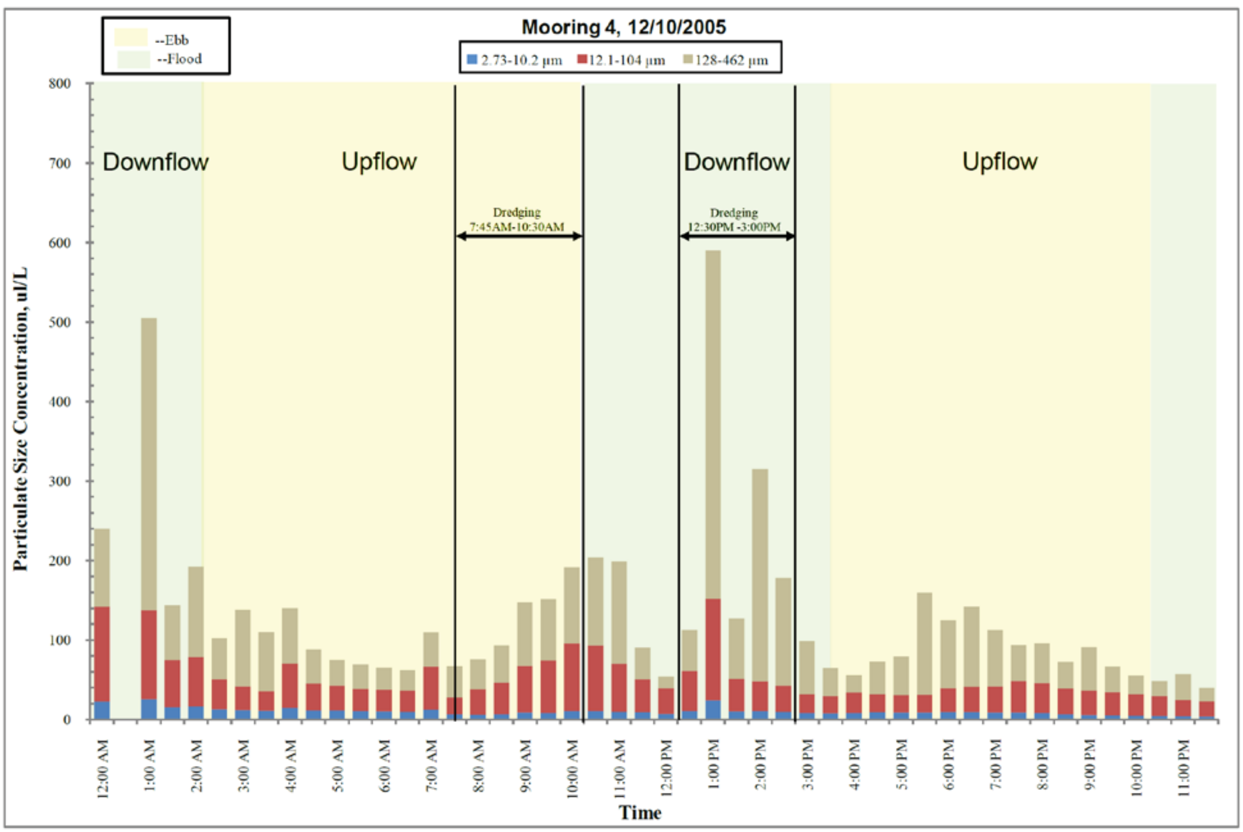


LISST Data for Mooring 3 on December 9, 2005 and Moorings 4 on December 9, 2005

Lower Passaic River Restoration Project

Figure 7-10

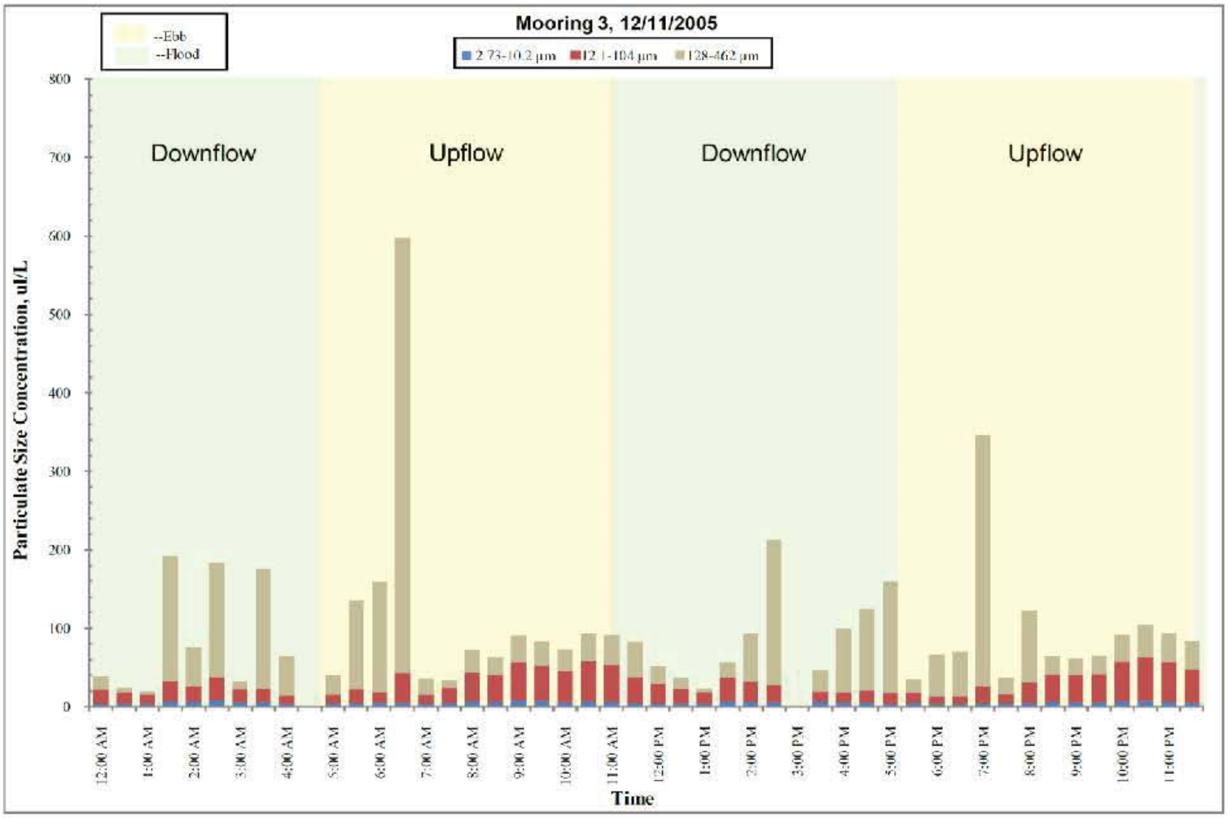


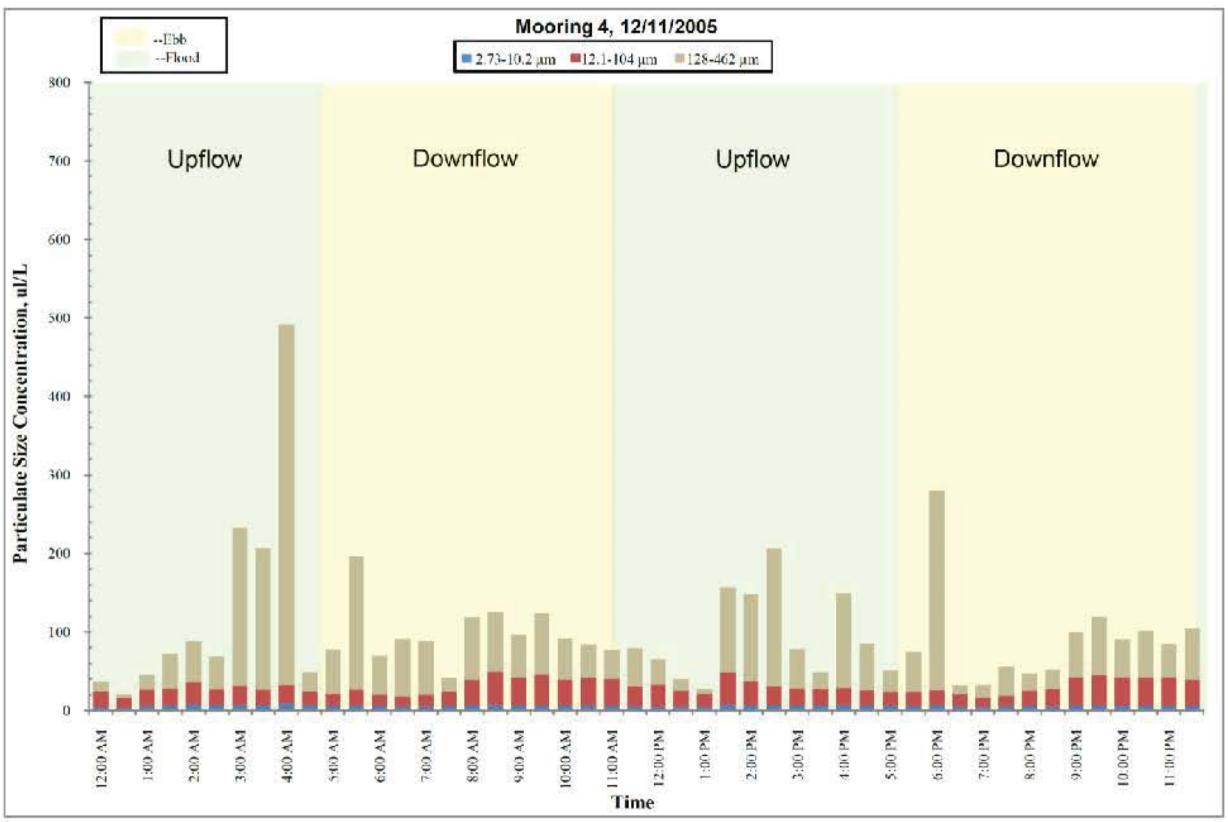


LISST Data for Mooring 3 on December 10, 2005 and Moorings 4 on December 10, 2005

Lower Passaic River Restoration Project

Figure 7-11

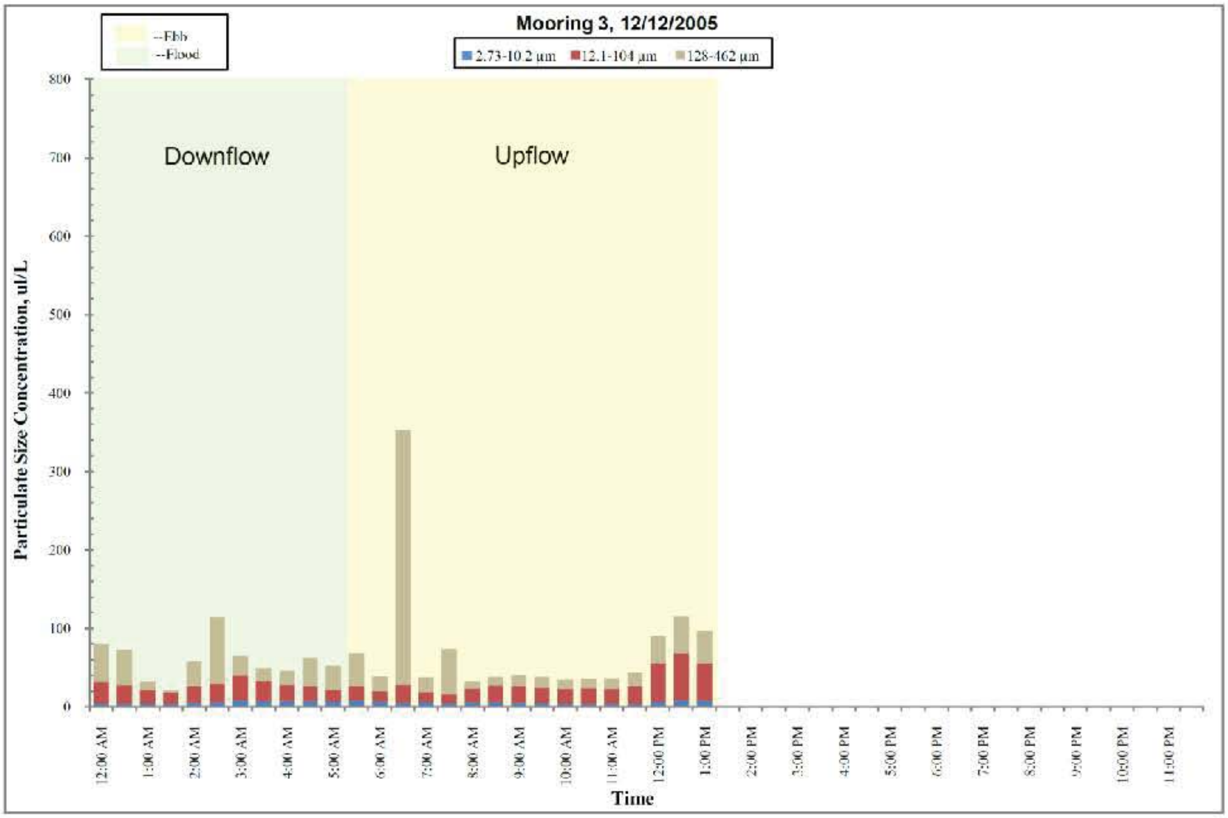


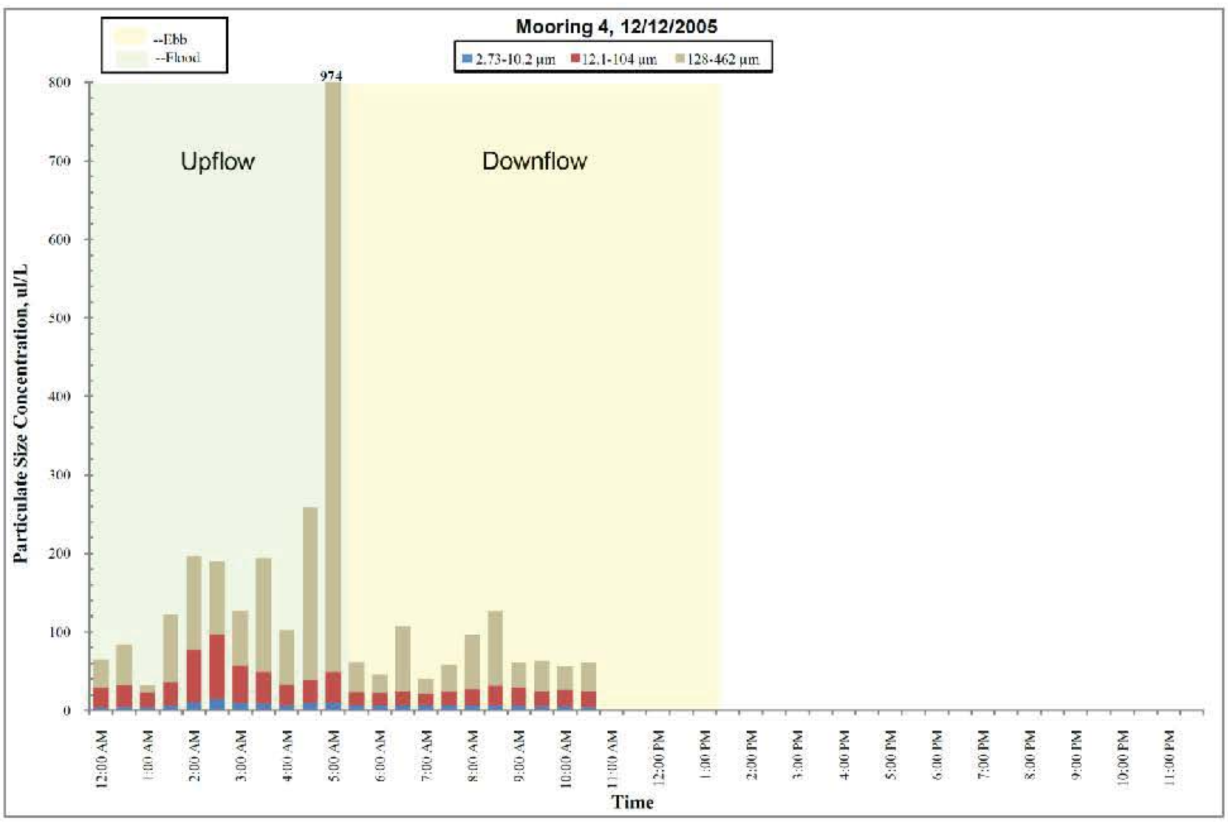


LISST Data for Mooring 3 on December 11, 2005 and Moorings 4 on December 11, 2005

Lower Passaic River Restoration Project

Figure 7-12

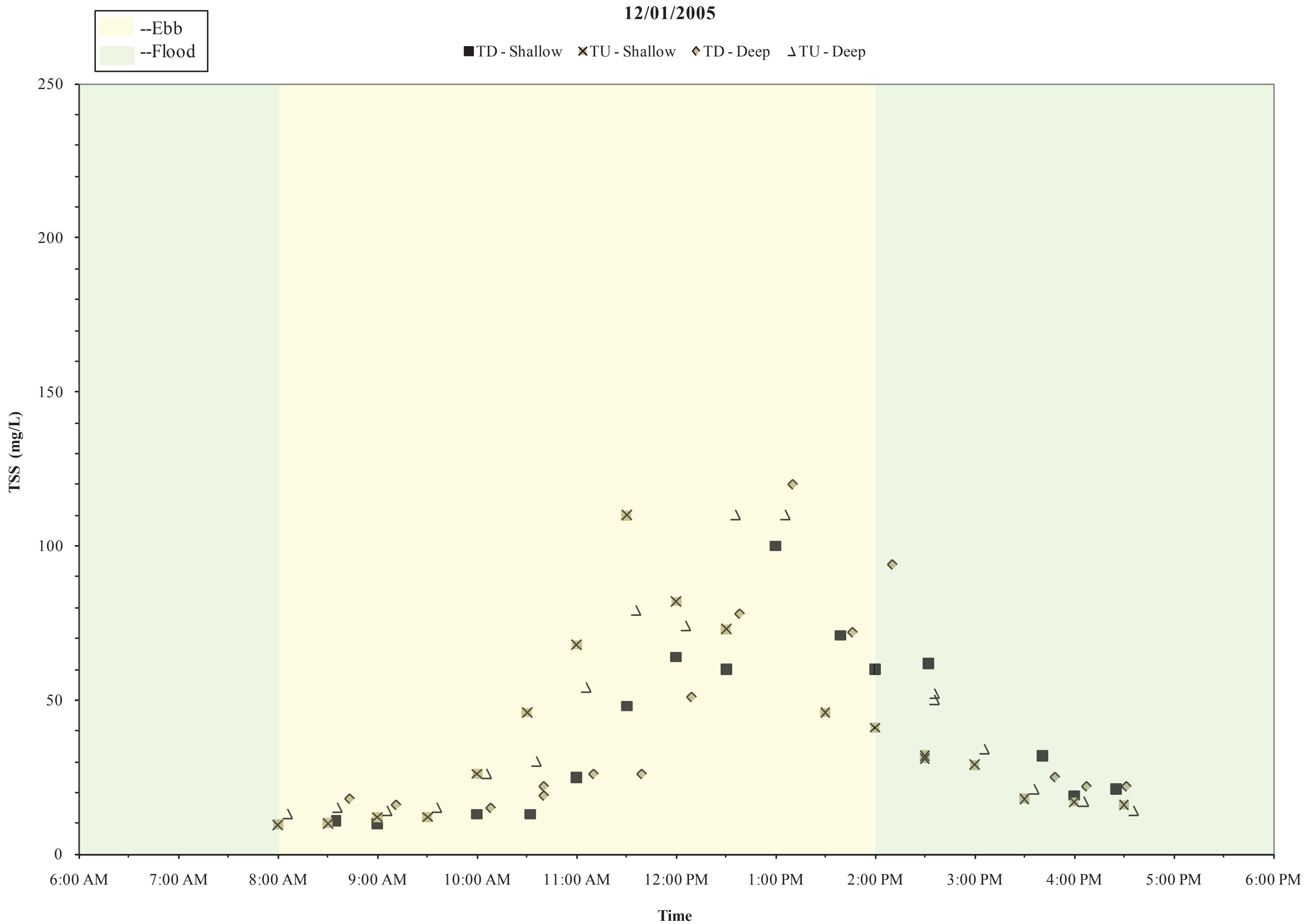




LISST Data for Mooring 3 on December 12, 2005 and Moorings 4 on December 12, 2005

Lower Passaic River Restoration Project

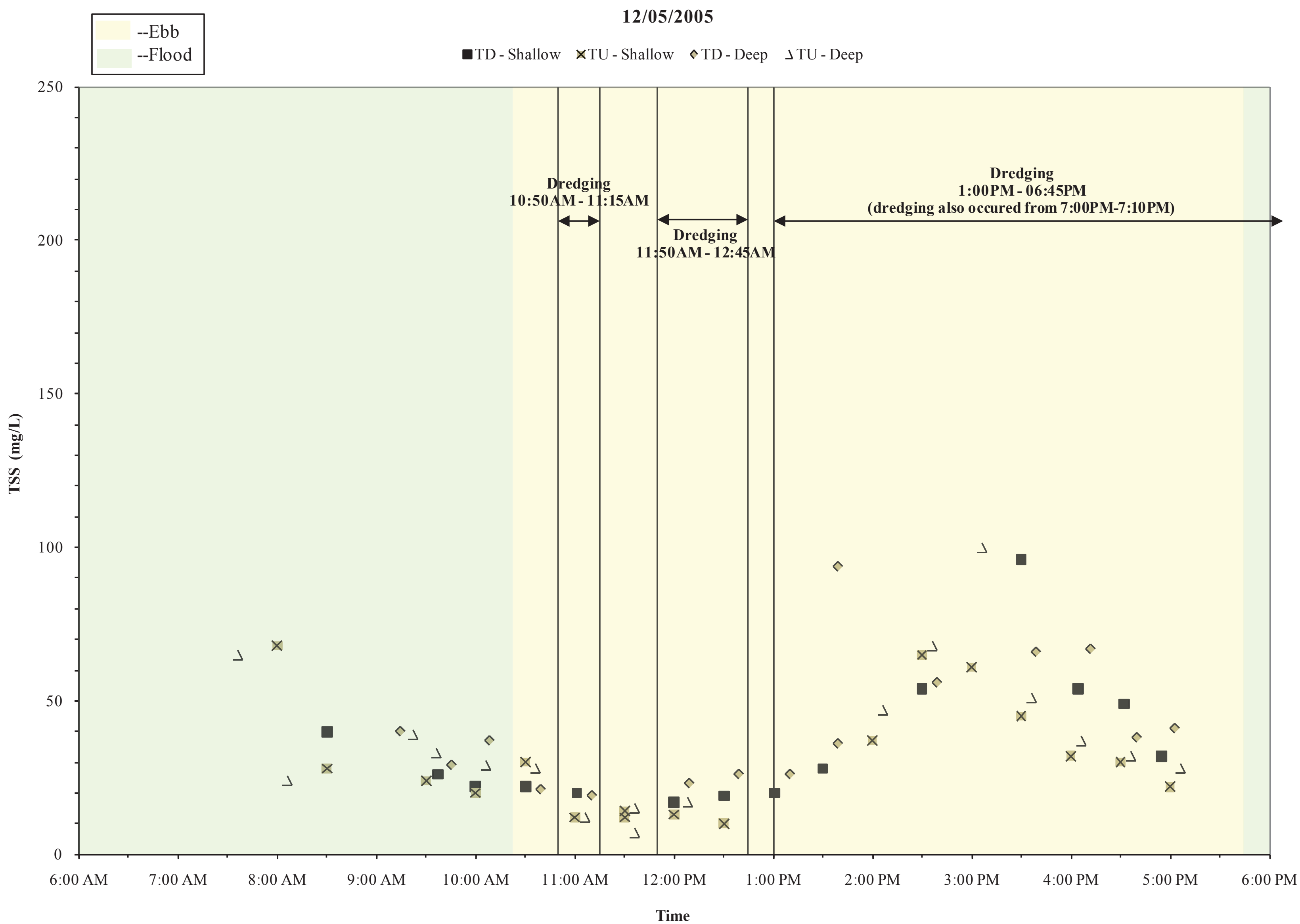
Figure 7-13



Pre-Dredging TSS Data Collected by TOPS Boats for December 1, 2005

Lower Passaic River Restoration Project

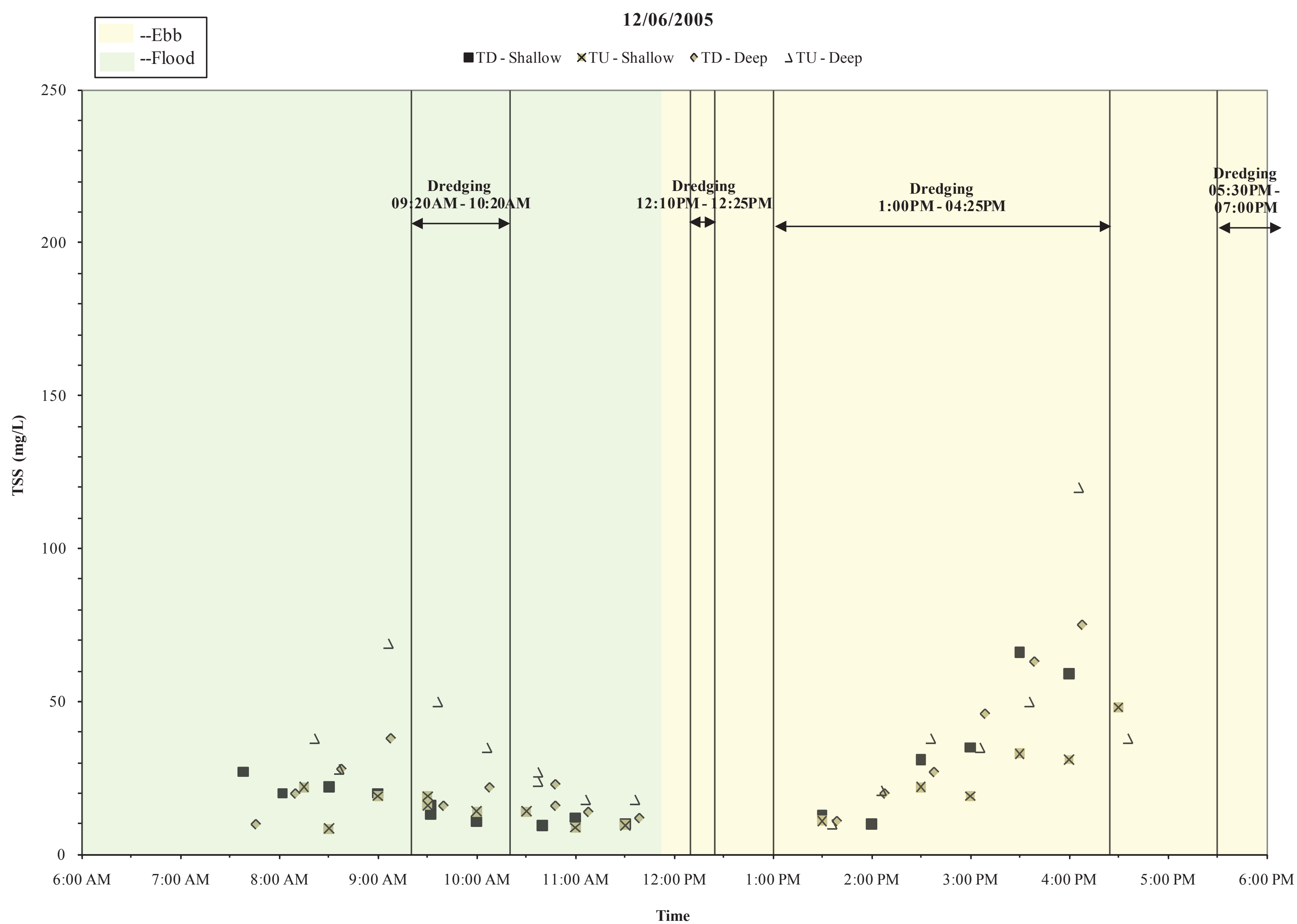
Figure 7-14



During Dredging TSS Data Collected by TOPS Boats for December 5, 2005

Lower Passaic River Restoration Project

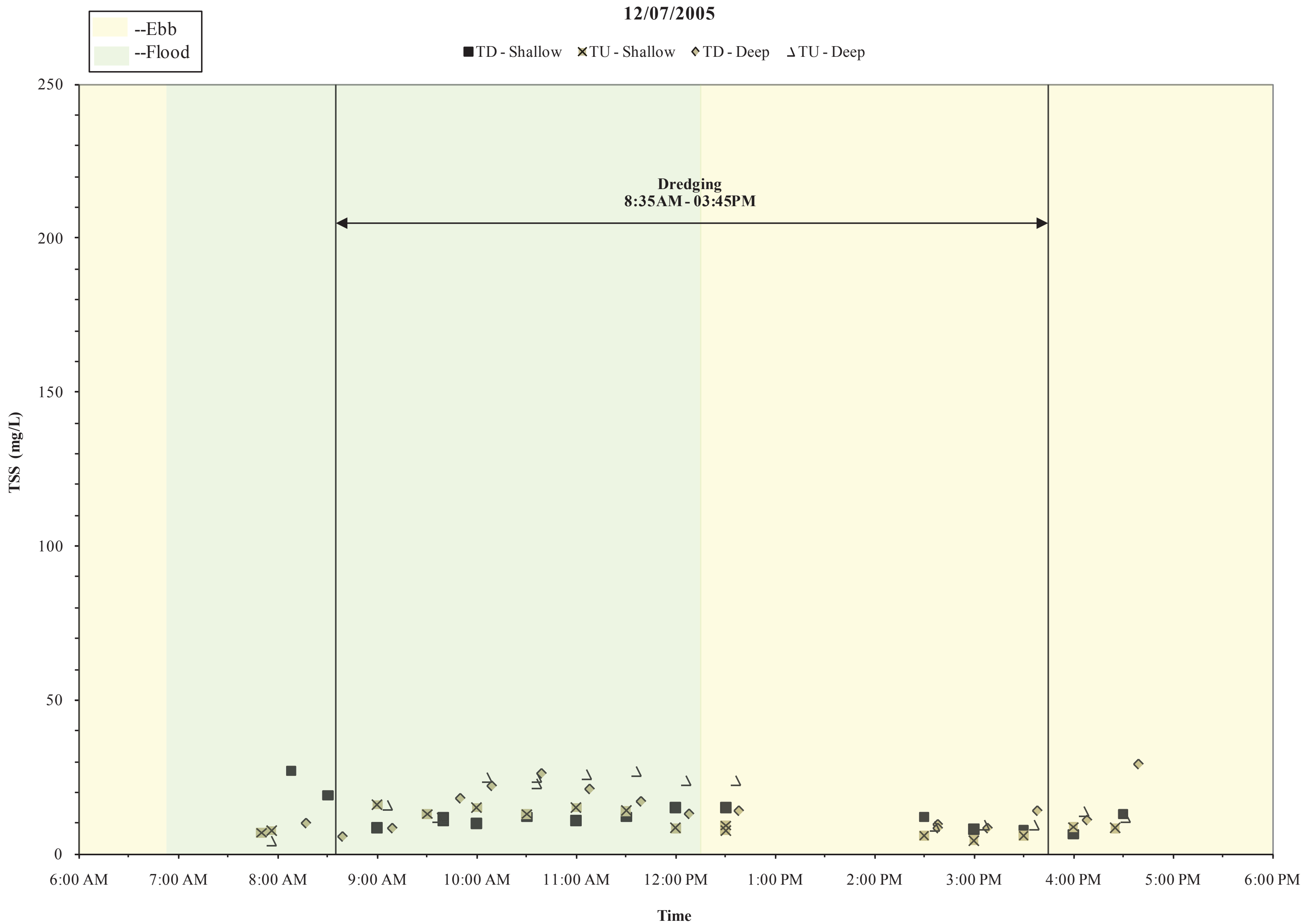
Figure 7-15



During Dredging TSS Data Collected by TOPS Boats for December 6, 2005

Lower Passaic River Restoration Project

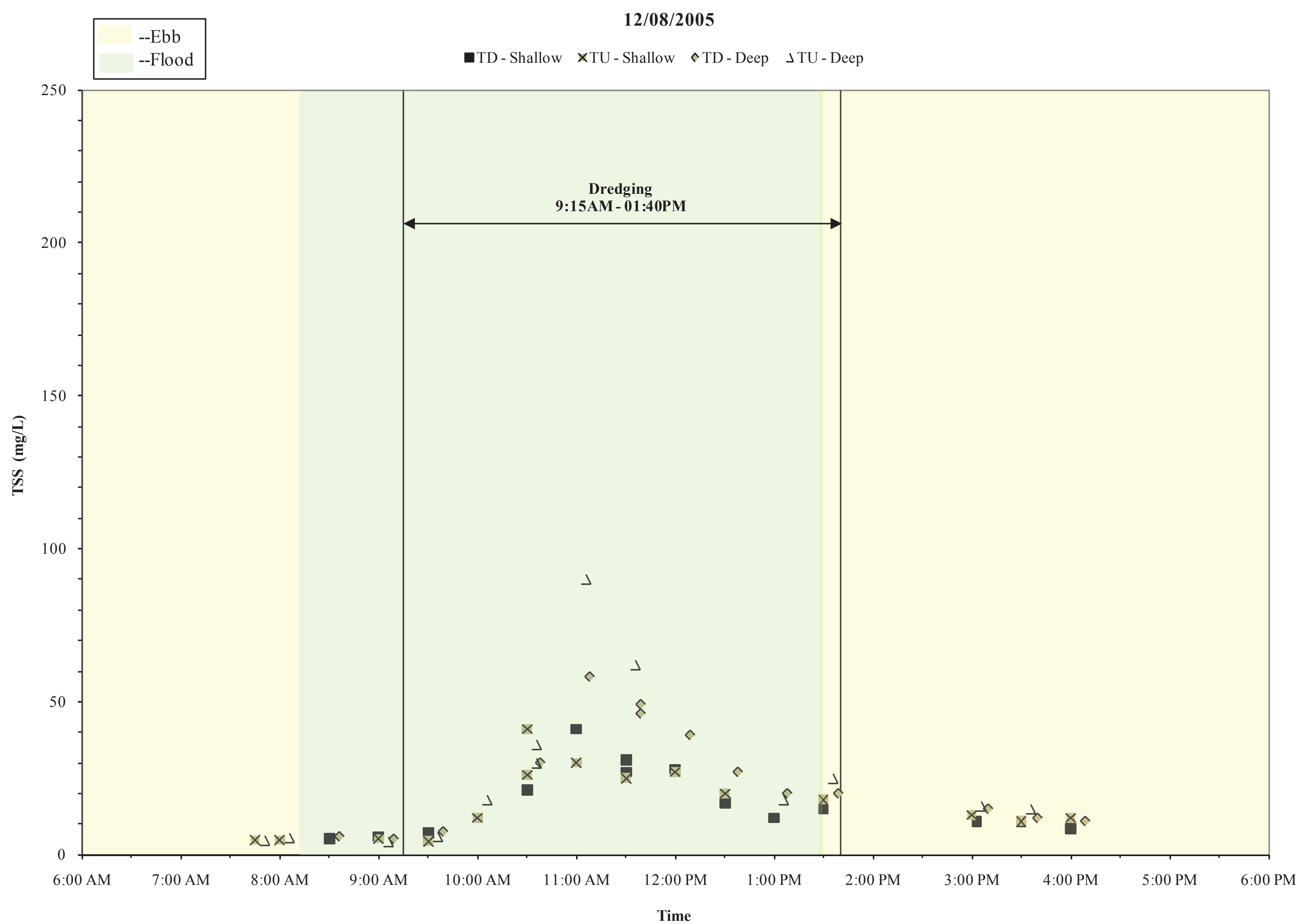
Figure 7-16



During Dredging TSS Data Collected by TOPS Boats for December 7, 2005

Lower Passaic River Restoration Project

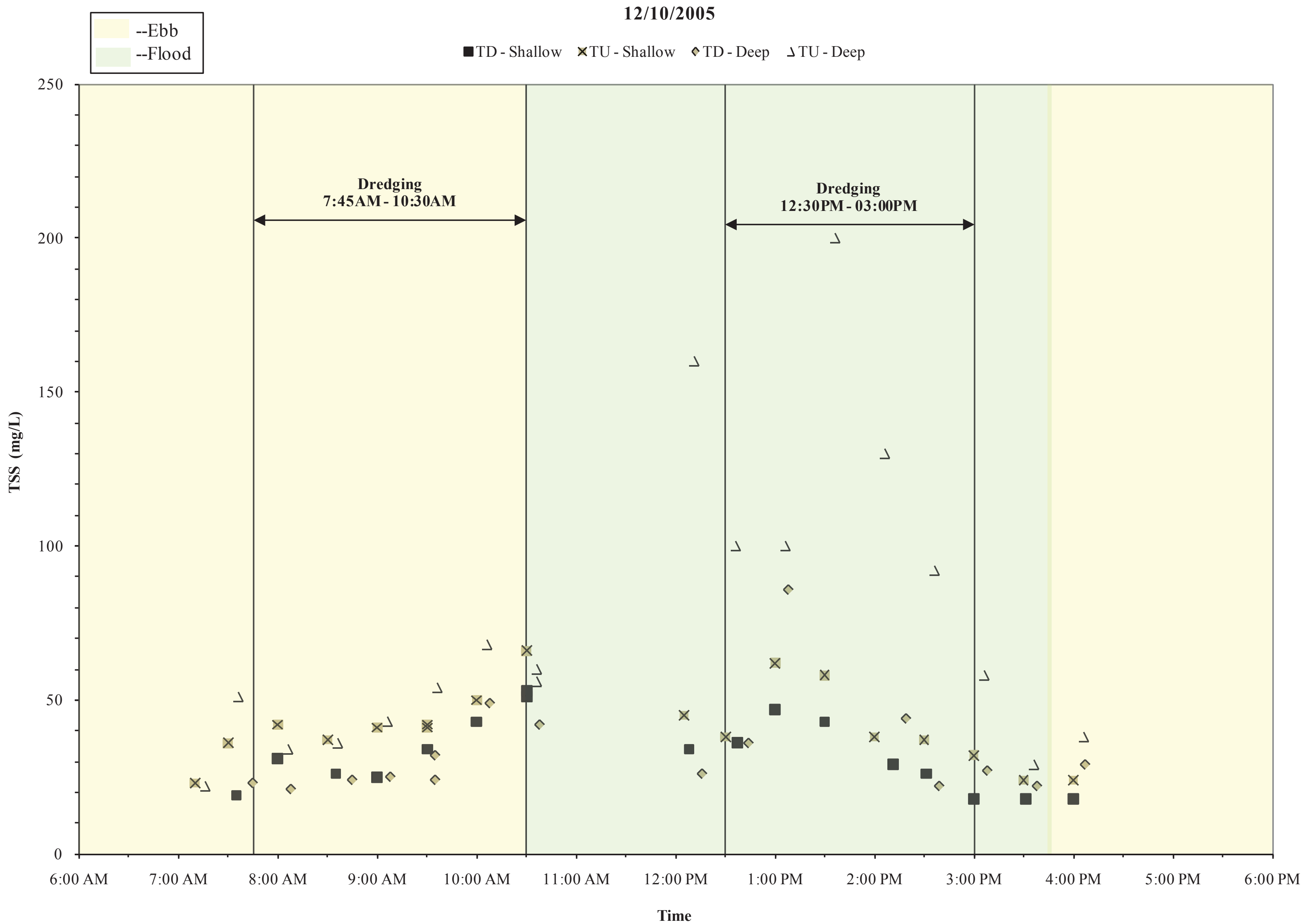
Figure 7-17



During Dredging TSS Data Collected by TOPS Boats for December 8, 2005

Lower Passaic River Restoration Project

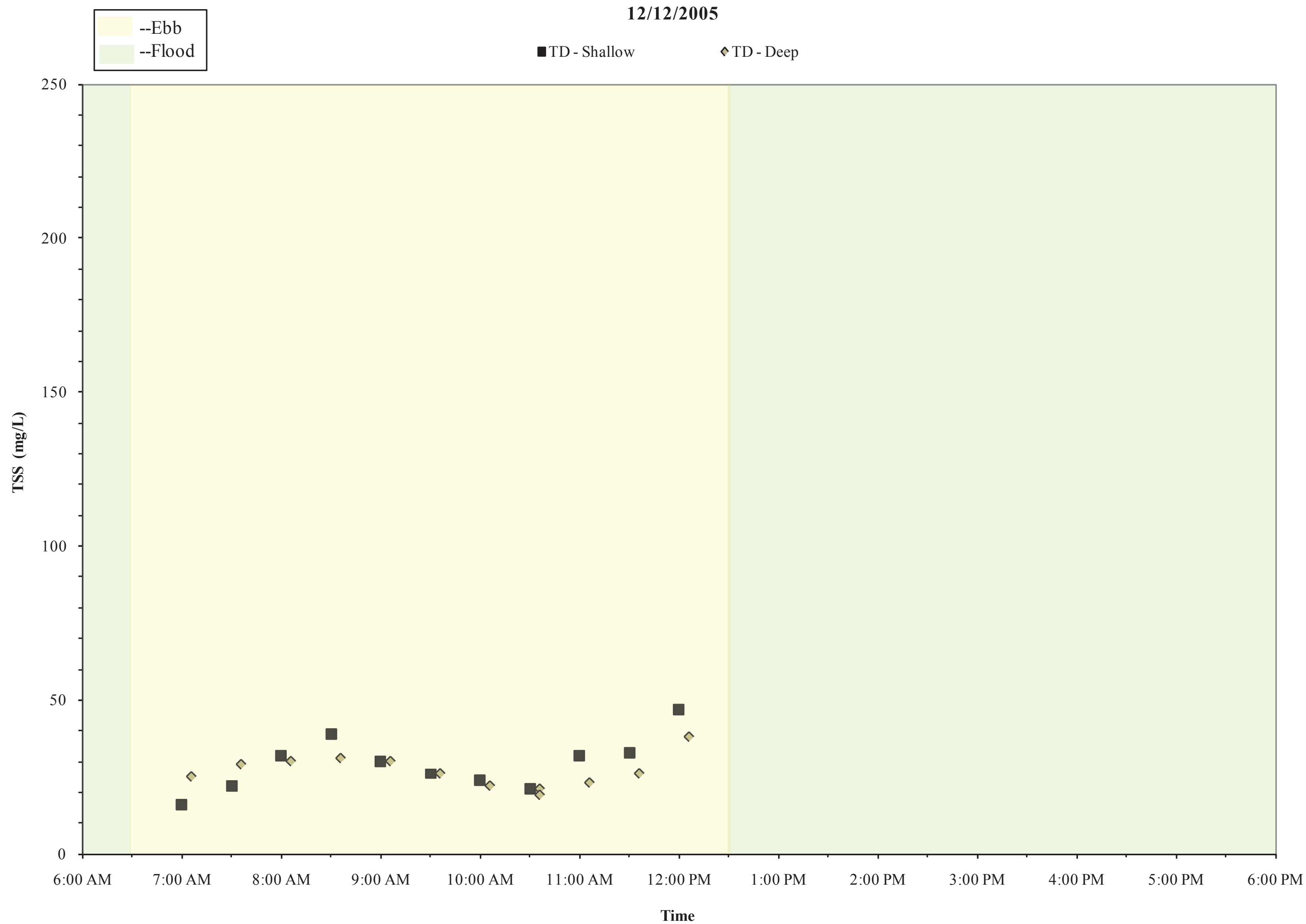
Figure 7-18



During Dredging TSS Data Collected by TOPS Boats for December 10, 2005

Lower Passaic River Restoration Project

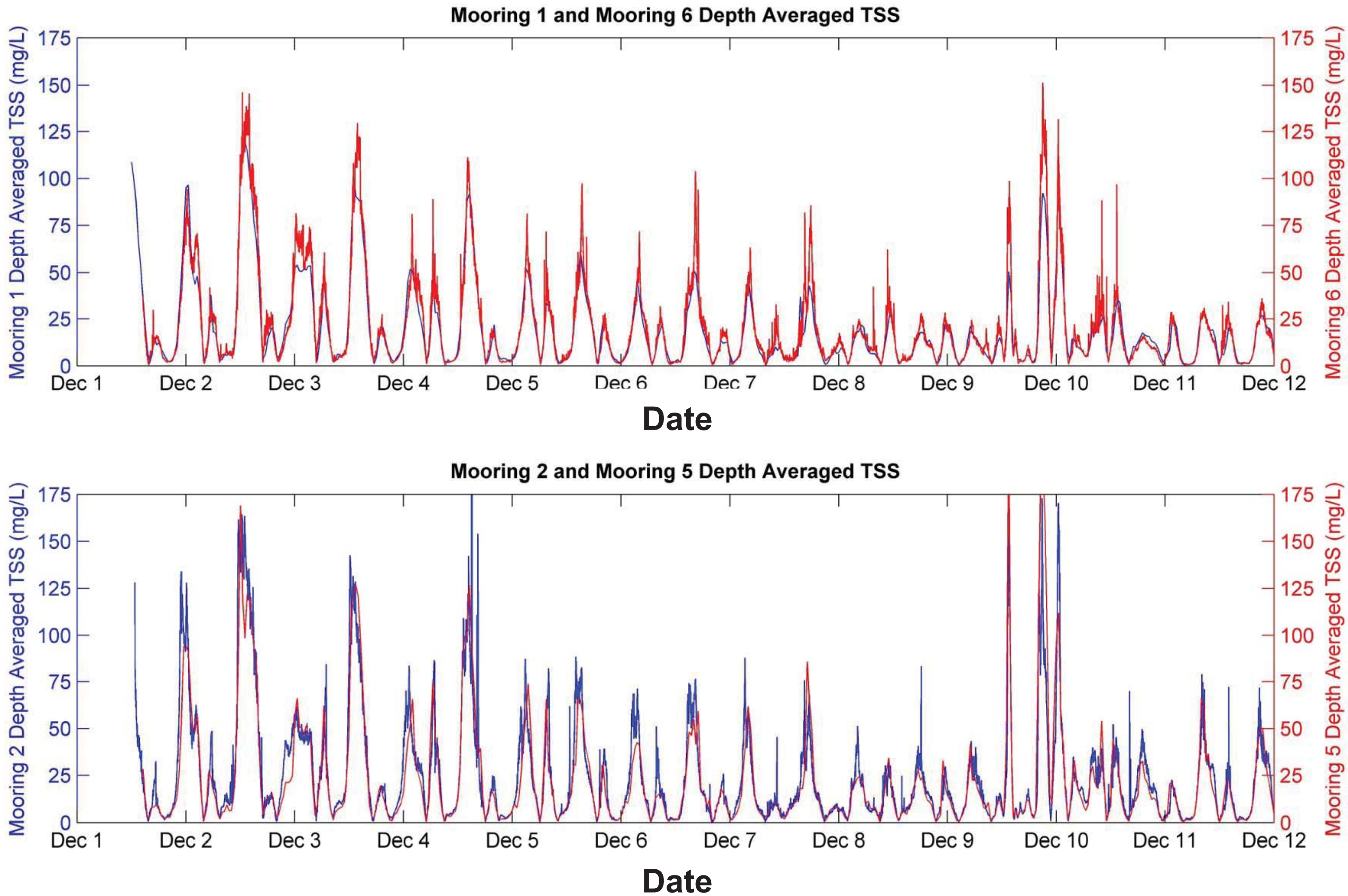
Figure 7-19



During Dredging TSS Data Collected by TOPS Boats for December 12, 2005

Lower Passaic River Restoration Project

Figure 7-20



Legend

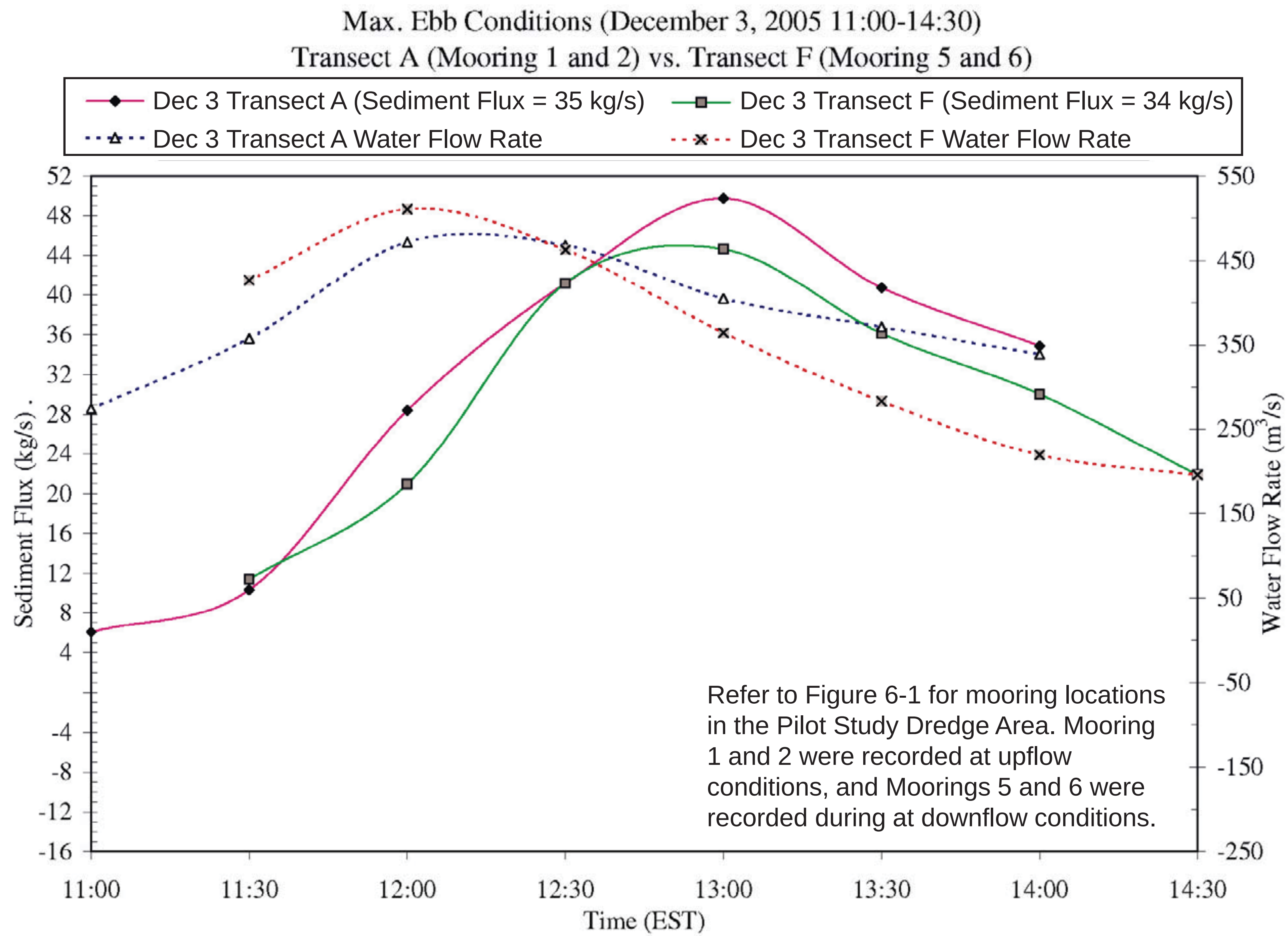
- Upriver
- Downriver

Note:
TSS is computed by the surrogate measured by the ADCP at the corresponding upriver and downriver moorings.

Comparison of Depth Averaged TSS at Moorings 1 & 6 (top panel) and Moorings 2 & 5 (bottom panel)

Lower Passaic River Restoration Project

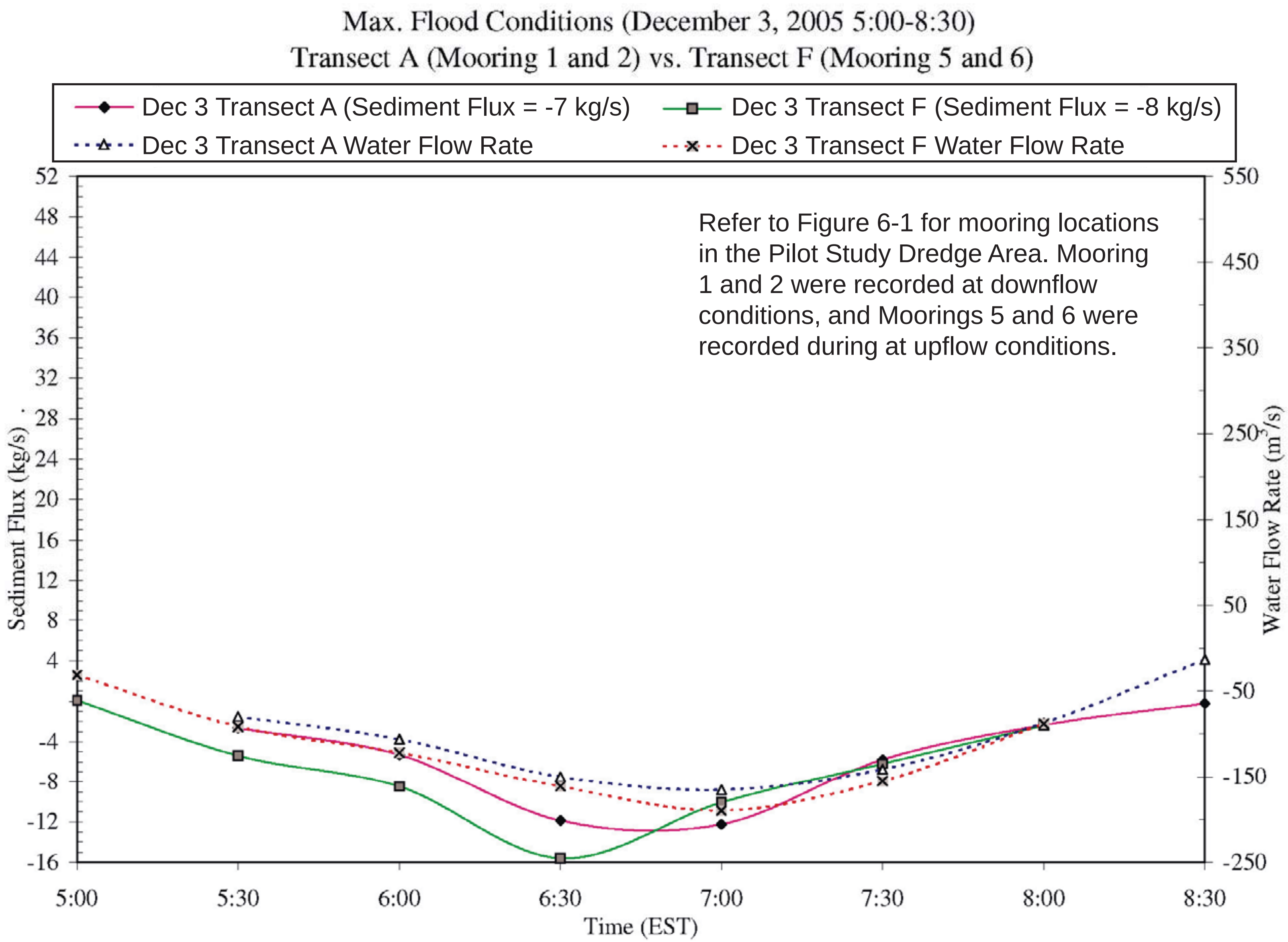
Figure 8-1



Suspended Sediment Flux under Maximum Ebb Conditions on December 3, 2005

Lower Passaic River Restoration Project

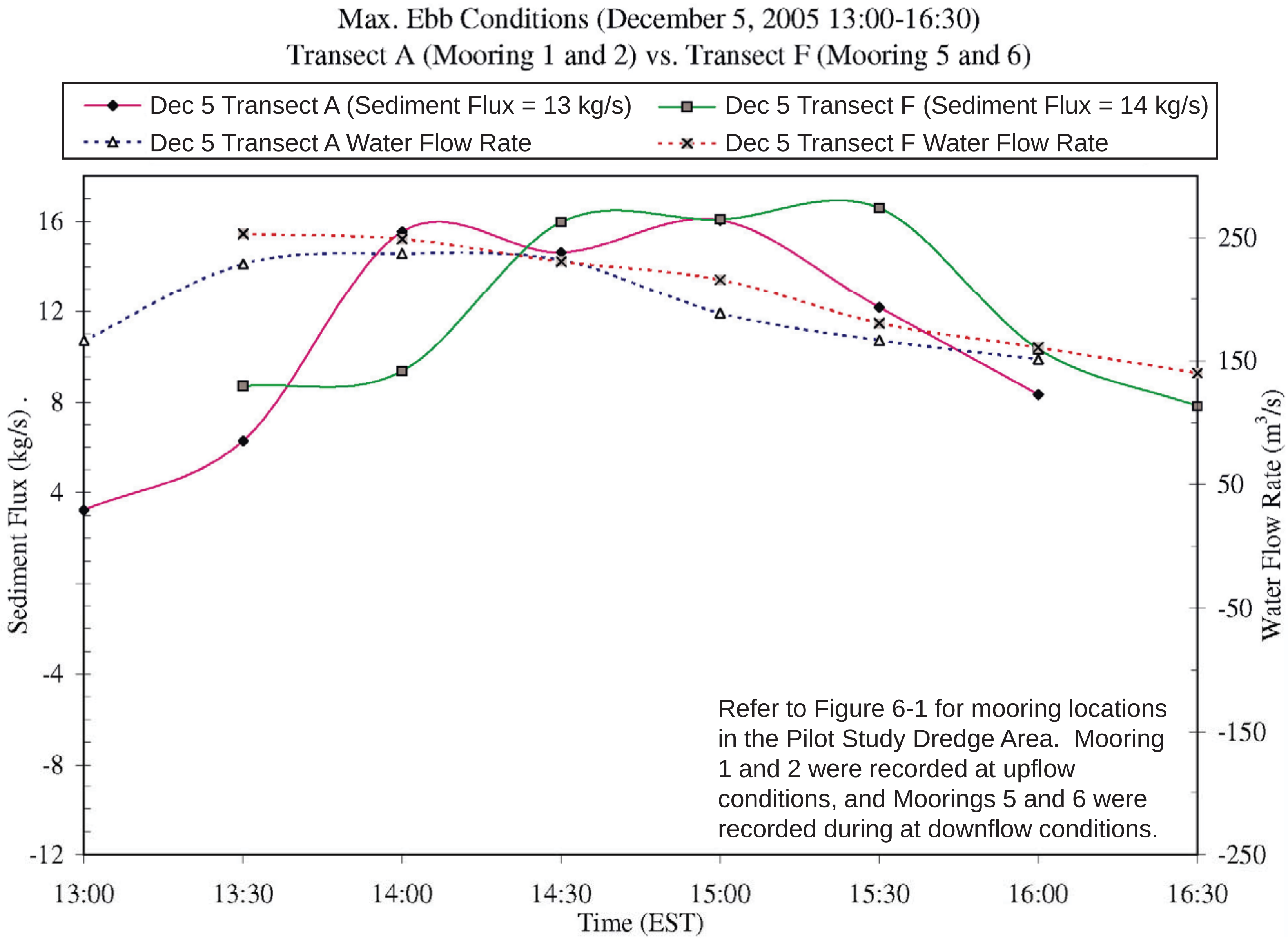
Figure 8-2



Suspended Sediment Flux under Maximum Flood Conditions on December 3, 2005

Lower Passaic River Restoration Project

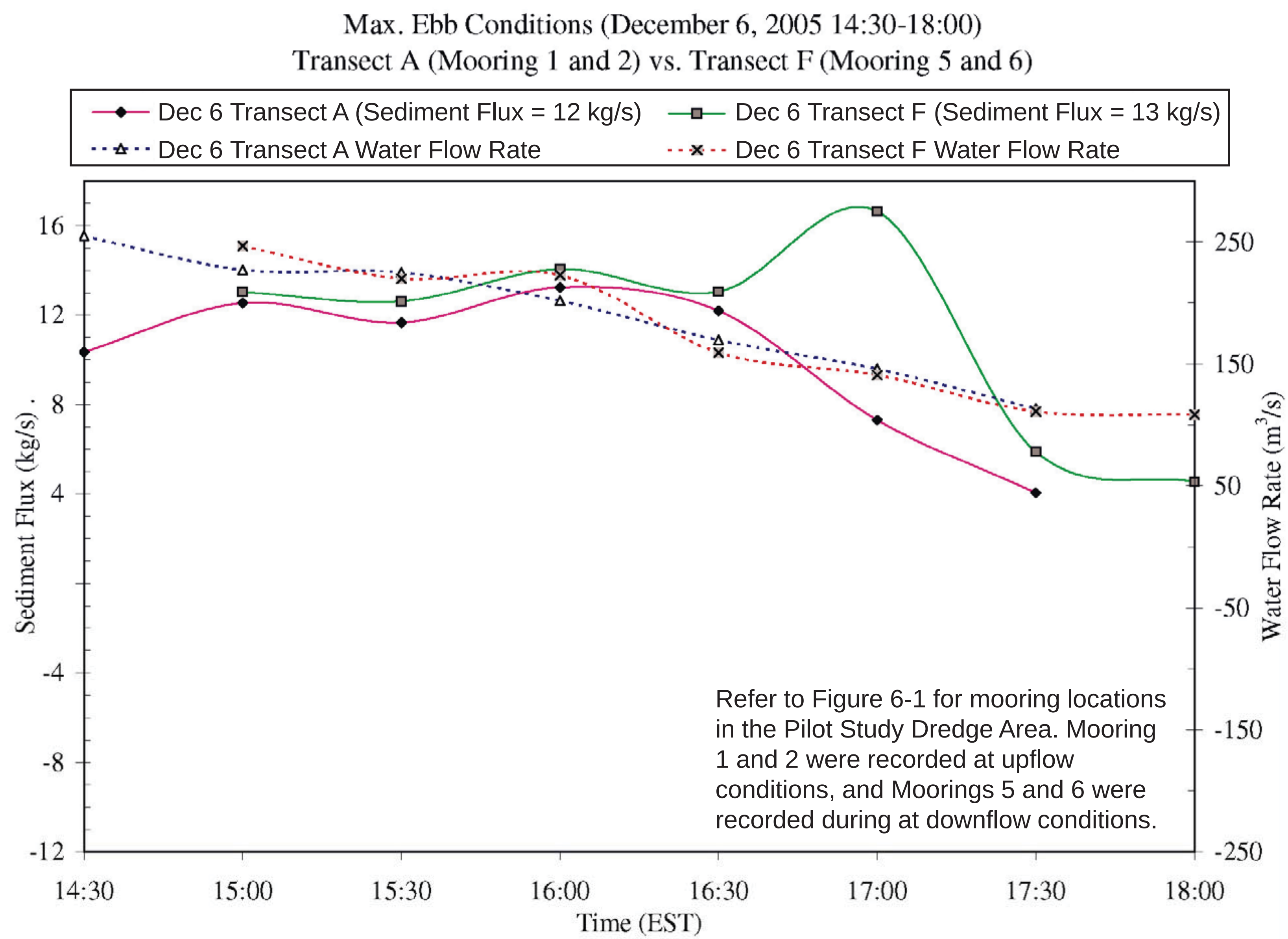
Figure 8-3



Suspended Sediment Flux under Maximum Ebb Conditions on December 5, 2005

Lower Passaic River Restoration Project

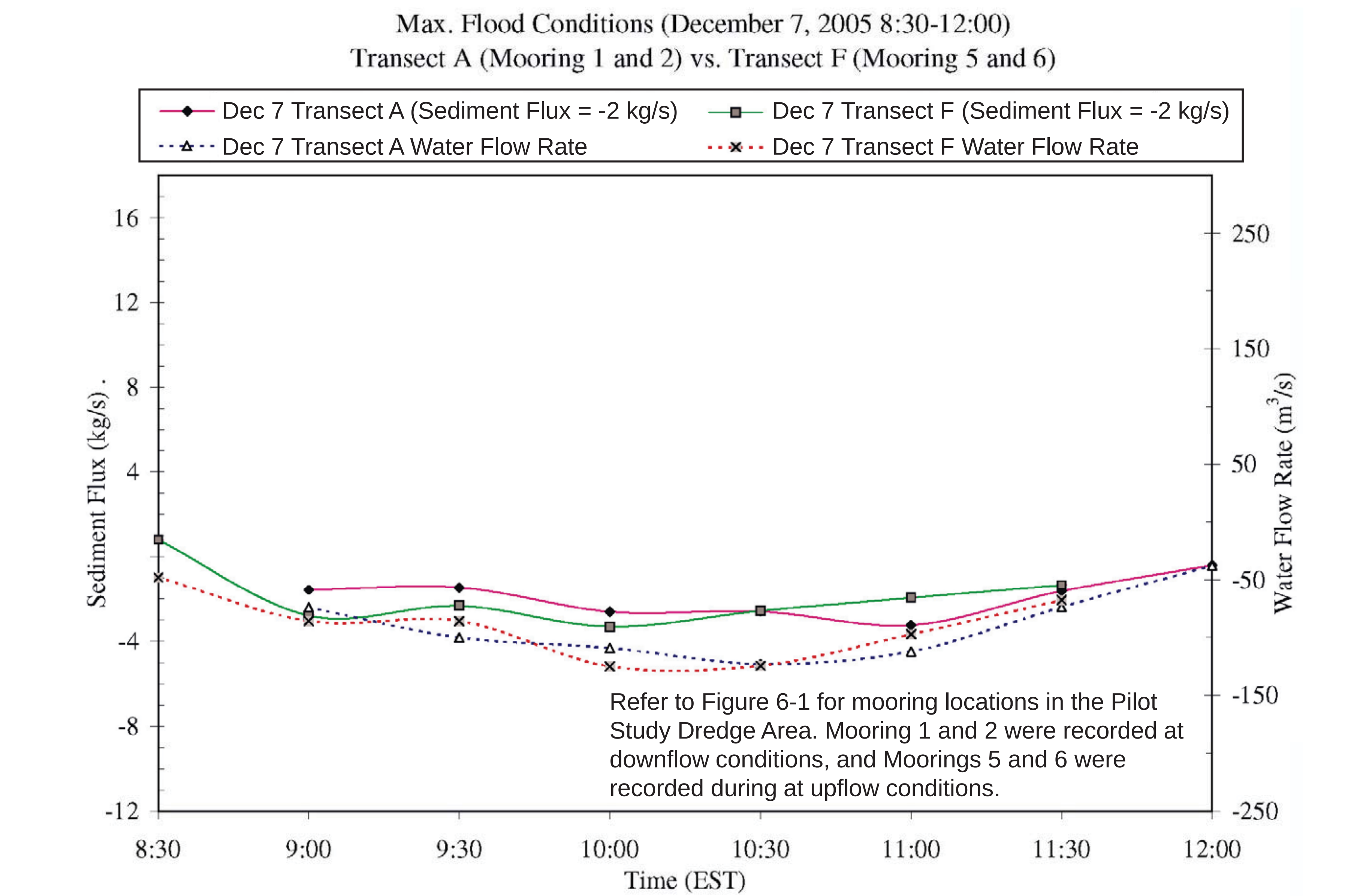
Figure 8-4



Suspended Sediment Flux under Maximum Ebb Conditions on December 6, 2005

Lower Passaic River Restoration Project

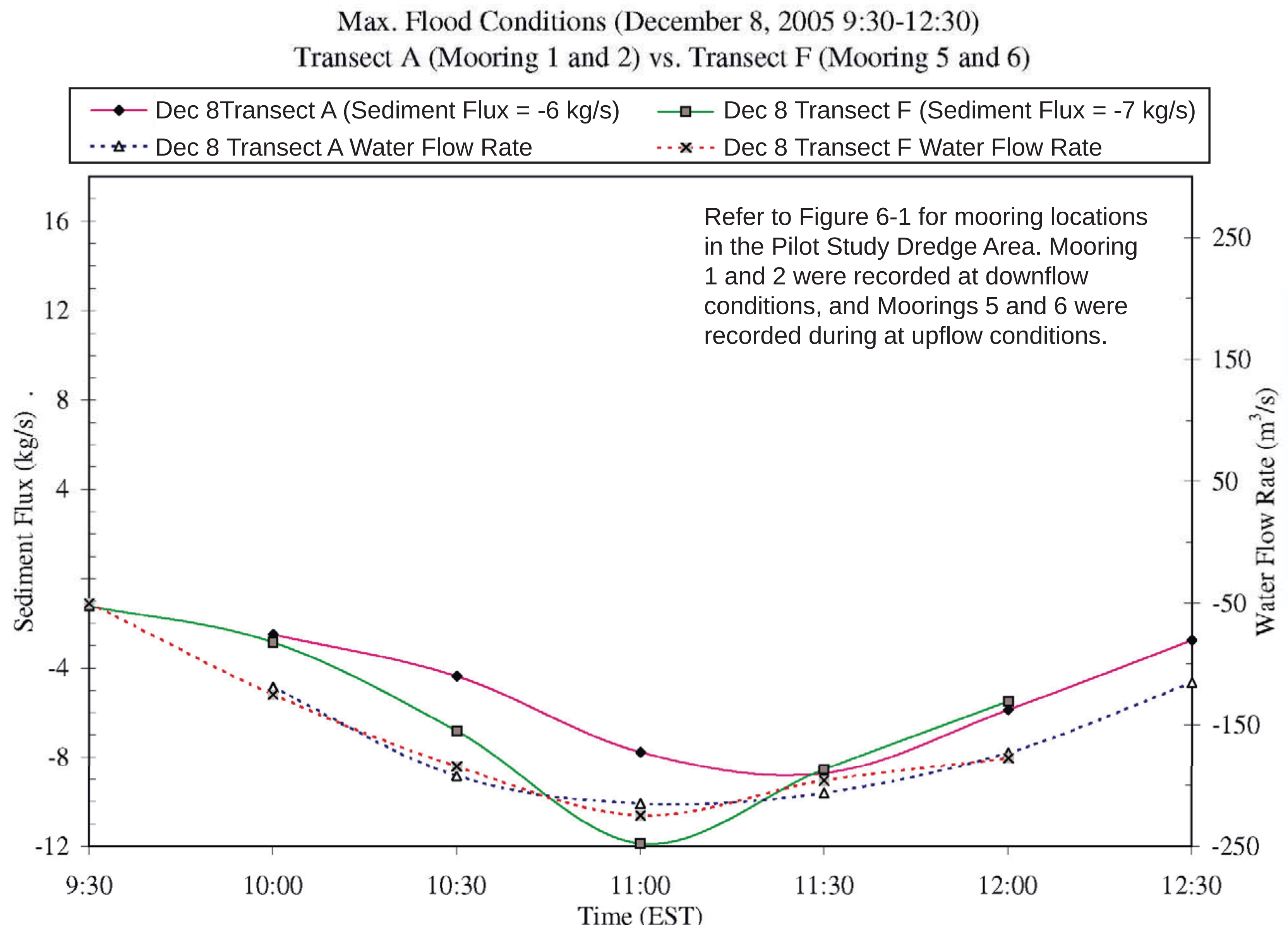
Figure 8-5



Suspended Sediment Flux under Maximum Flood Conditions on December 7, 2005

Lower Passaic River Restoration Project

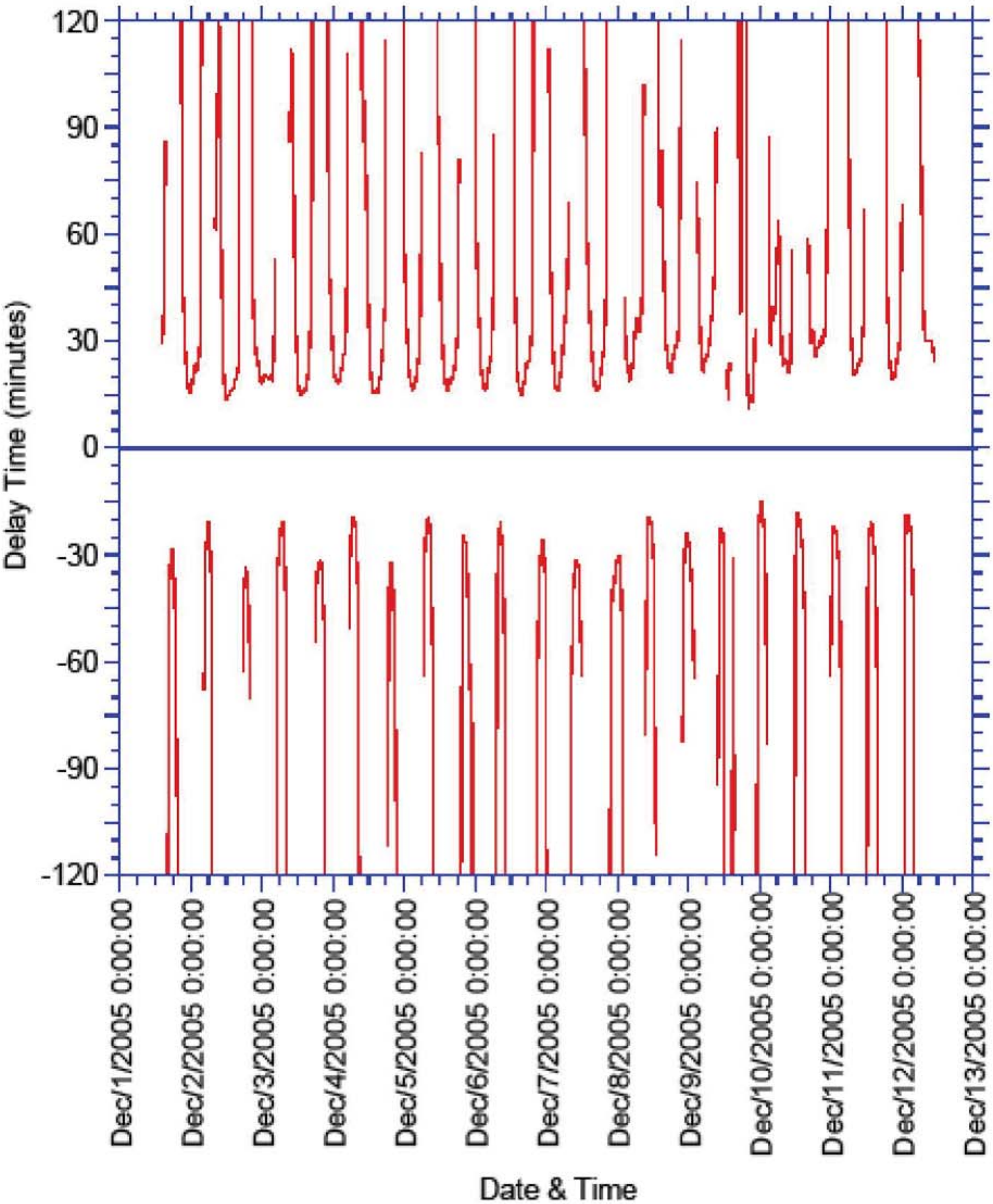
Figure 8-6



Suspended Sediment Flux under Maximum Flood Conditions on December 8, 2005

Lower Passaic River Restoration Project

Figure 8-7

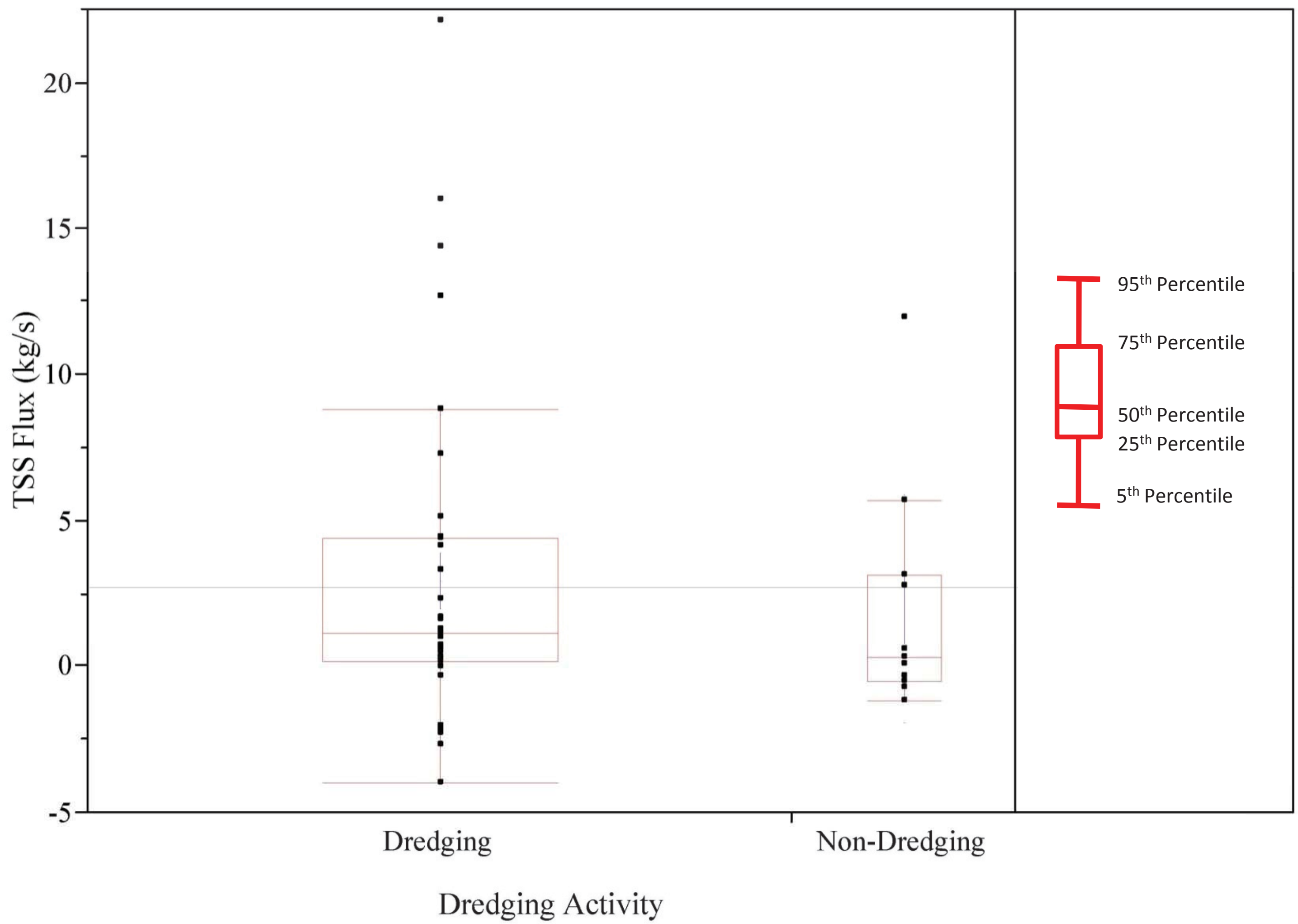


Positive values occur on ebb tides, and negative values occur during flood tides.

Delay Times Between Upriver Moorings 1 and 2 (Transect A) and Downriver Moorings 5 and 6 (Transect F)

Lower Passaic River Restoration Project

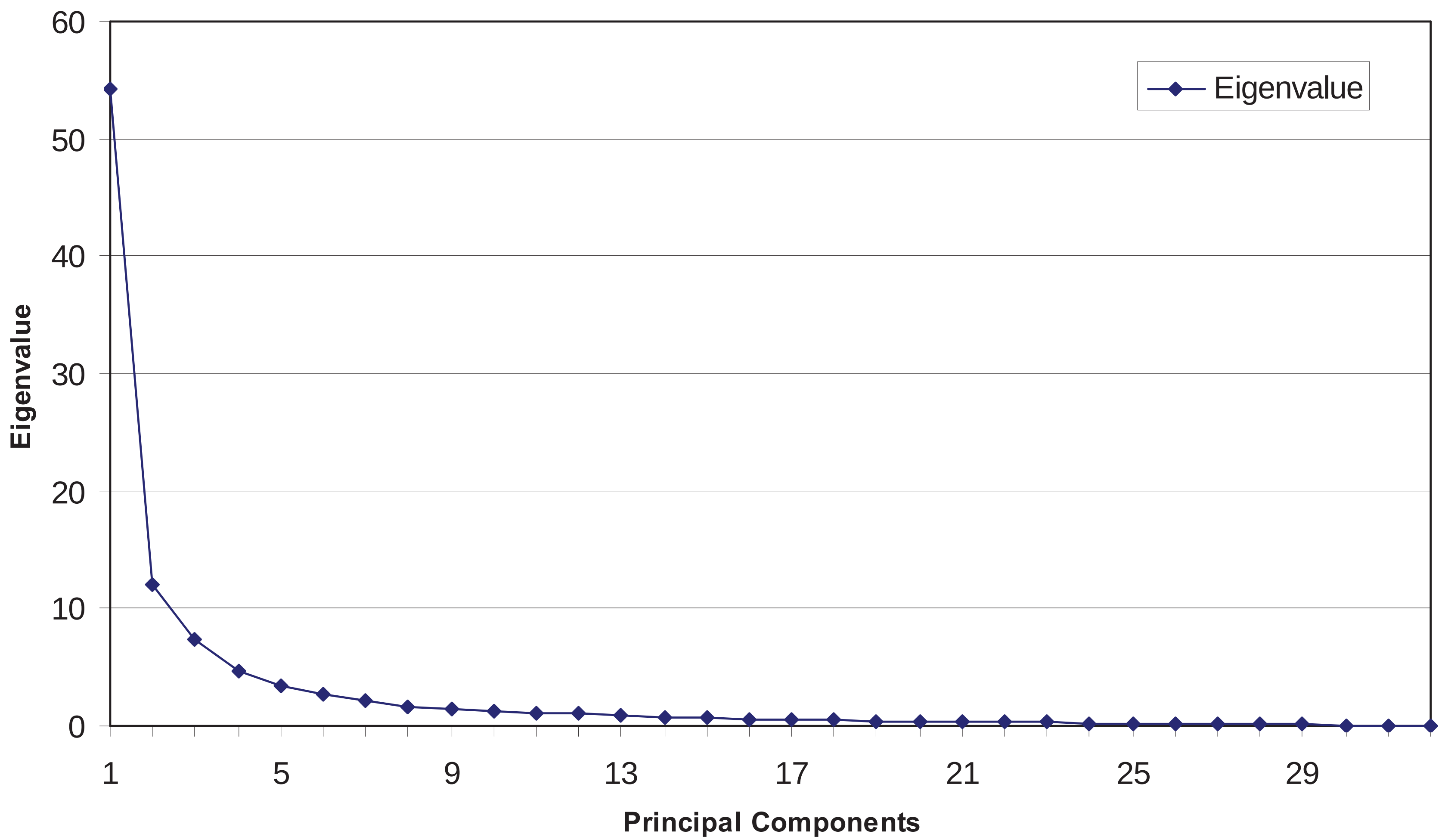
Figure 8-8



Statistical Results of Tukey-Kramer Test Comparing Net Suspended Sediment Flux in the Far-field during Dredging and Non-Dredging Activity Periods

Lower Passaic River Restoration Project

Figure 8-9

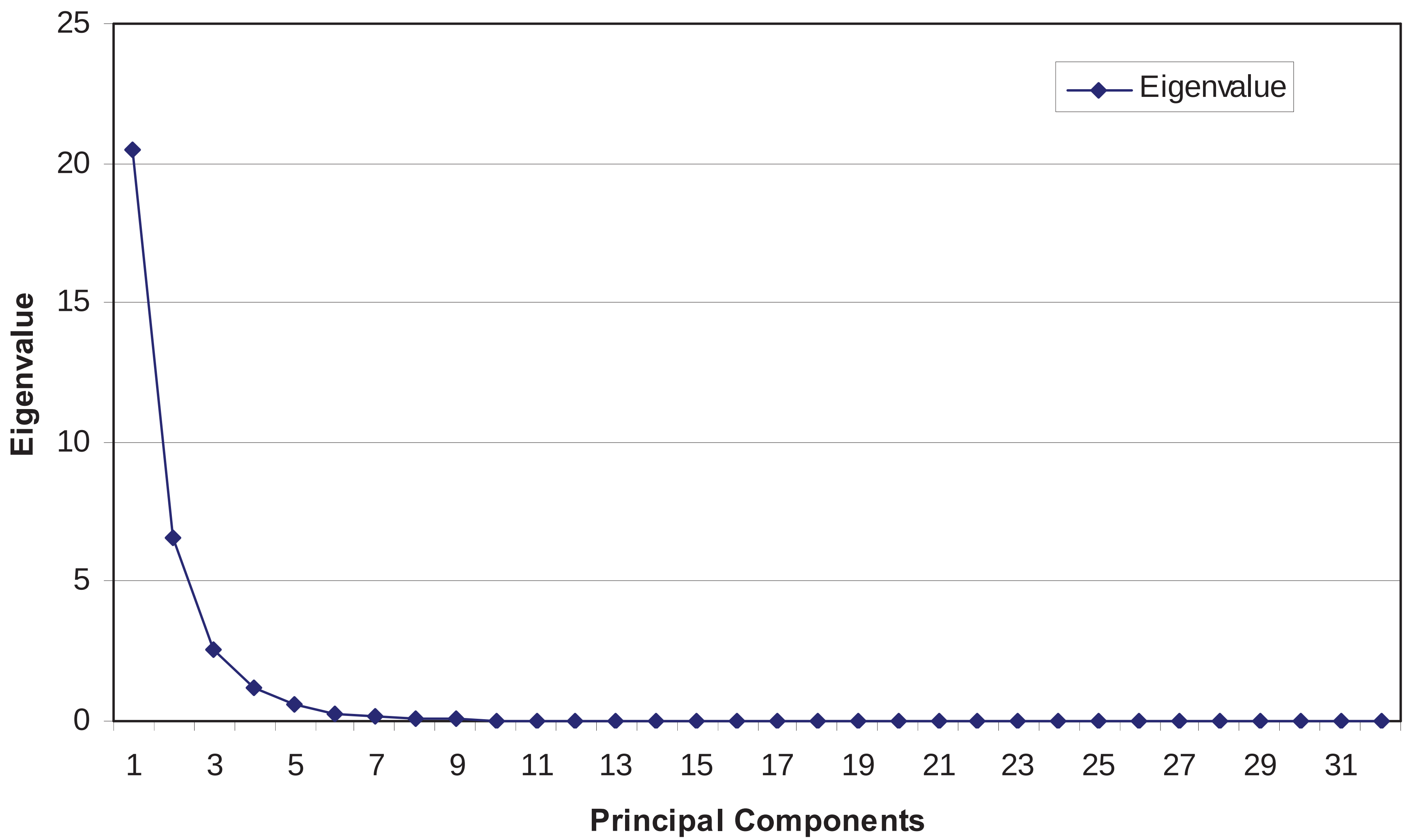


US Army Corps of Engineers

Eigenvector Decomposition for LISST Data Collected on *R/V Julia Miller*

Lower Passaic River Restoration Project

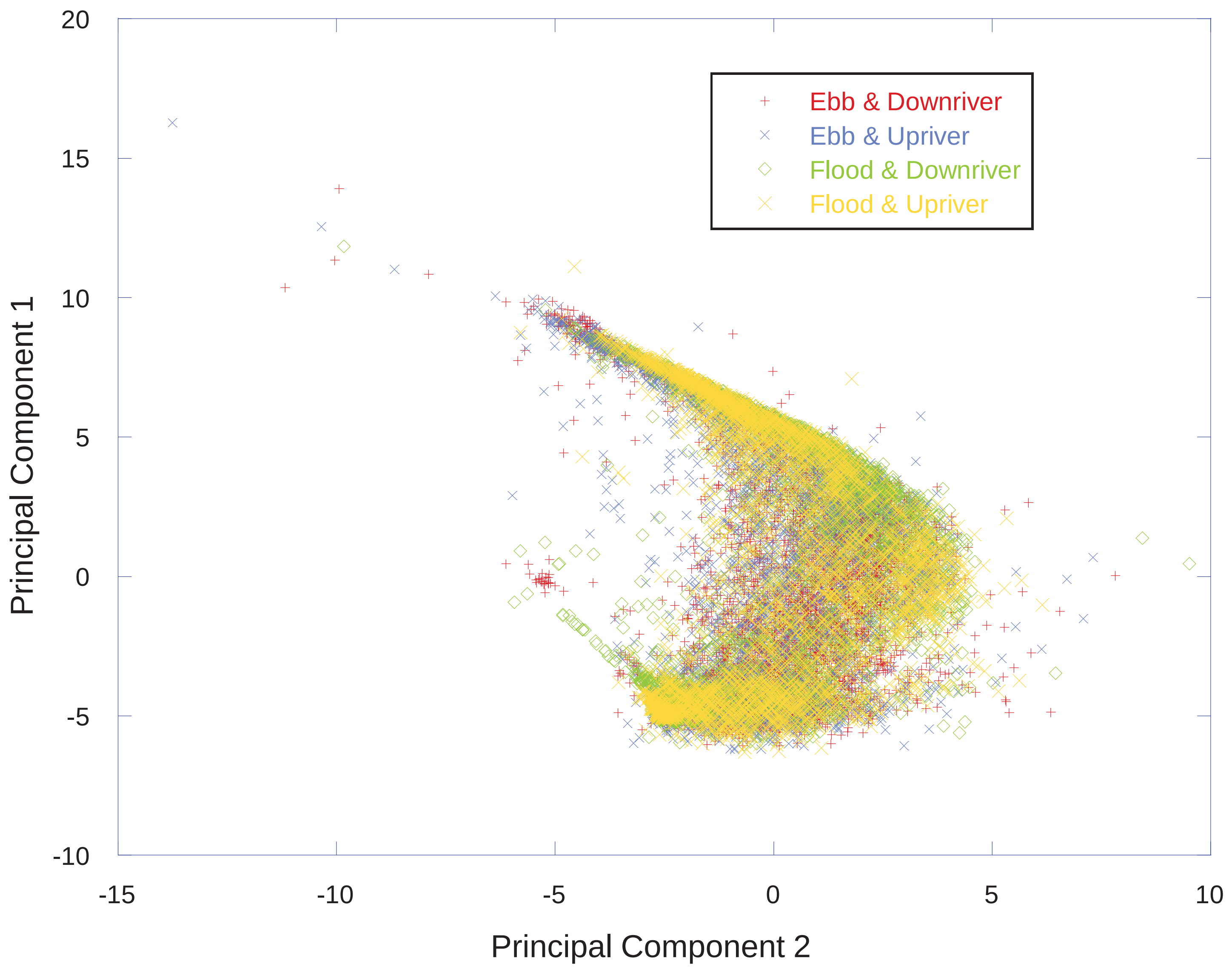
Figure 8-10



Eigenvector Decomposition for LISST Data Collected on Moorings 3 and 4

Lower Passaic River Restoration Project

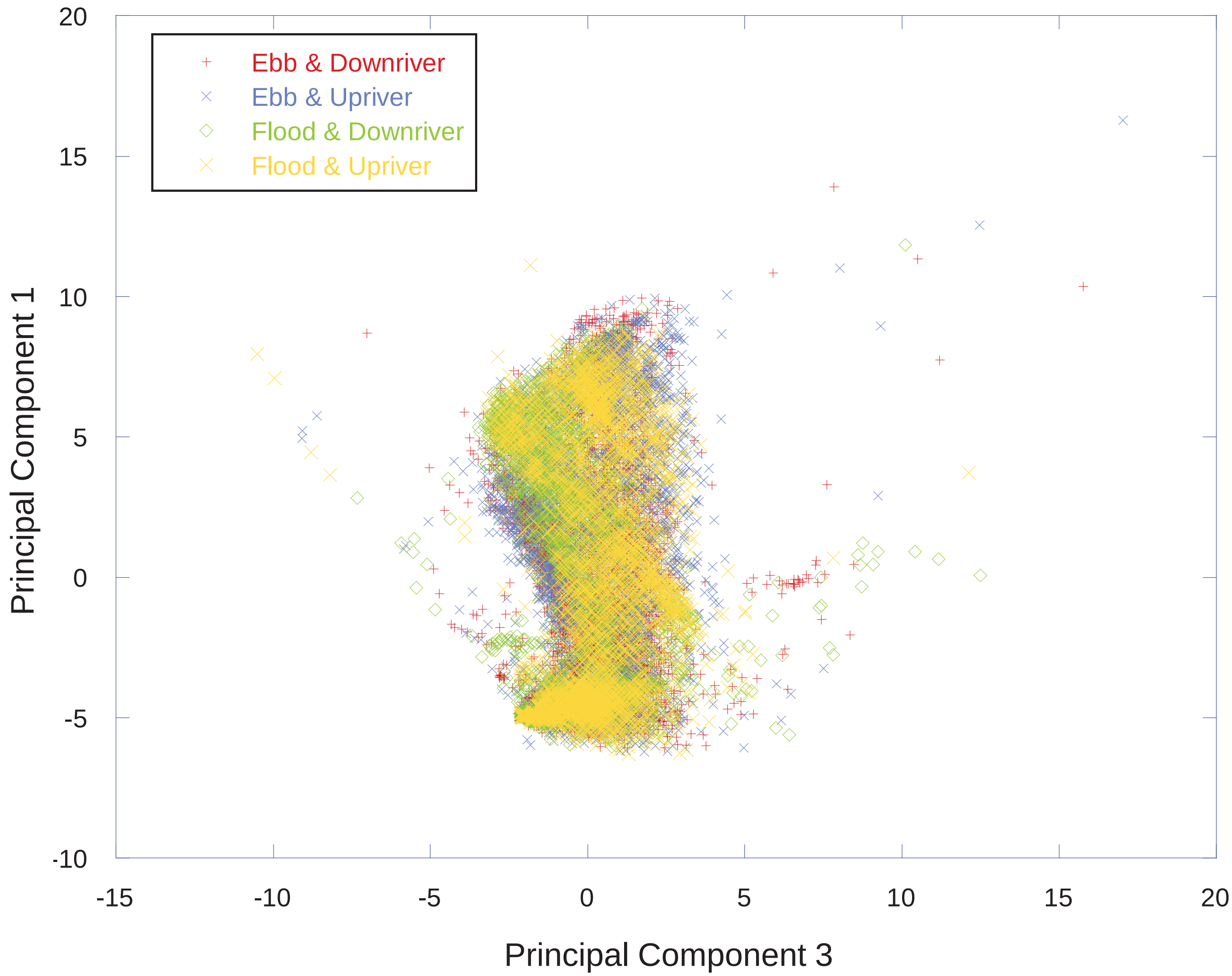
Figure 8-11



Principal Component 1 versus Principal Component 2 for the LISST Data Collected on *R/V Julia Miller*

Lower Passaic River Restoration Project

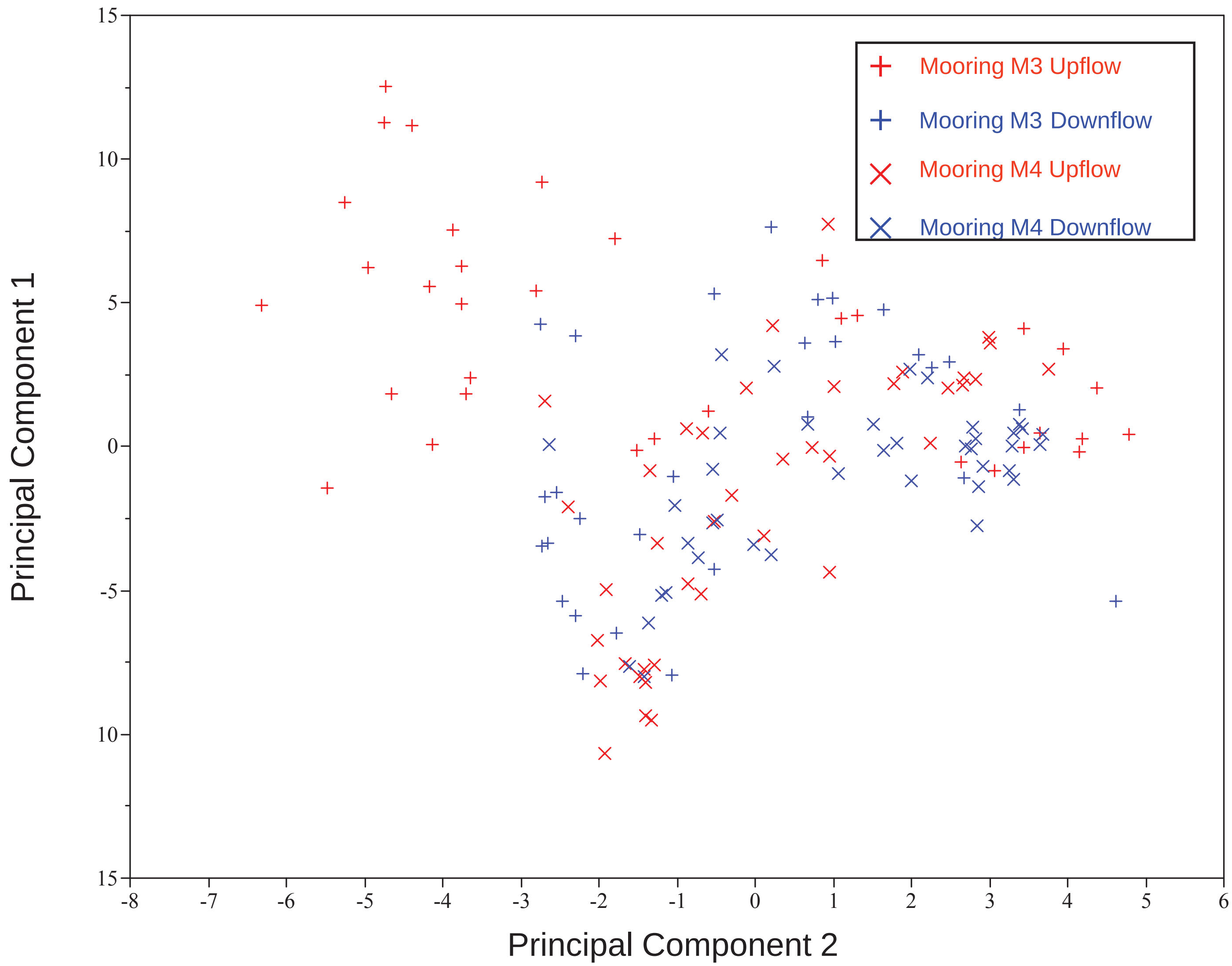
Figure 8-12



Principal Component 1 versus Principal Component 3 for the LISST Data Collected on *R/V Julia Miller*

Lower Passaic River Restoration Project

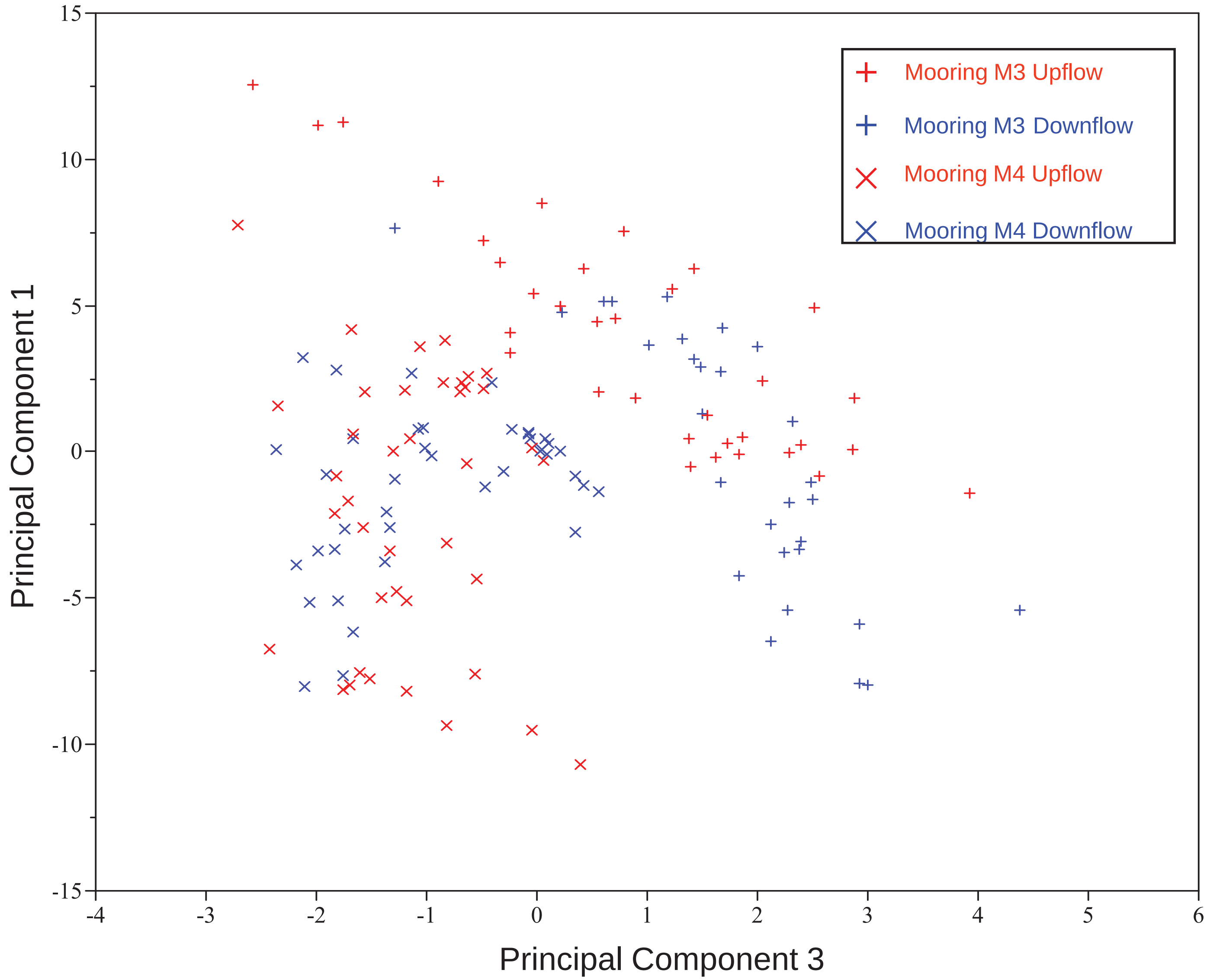
Figure 8-13



Principal Component 1 versus Principal Component 2 for the LISST Data Collected on Mooring 3 and Mooring 4

Lower Passaic River Restoration Project

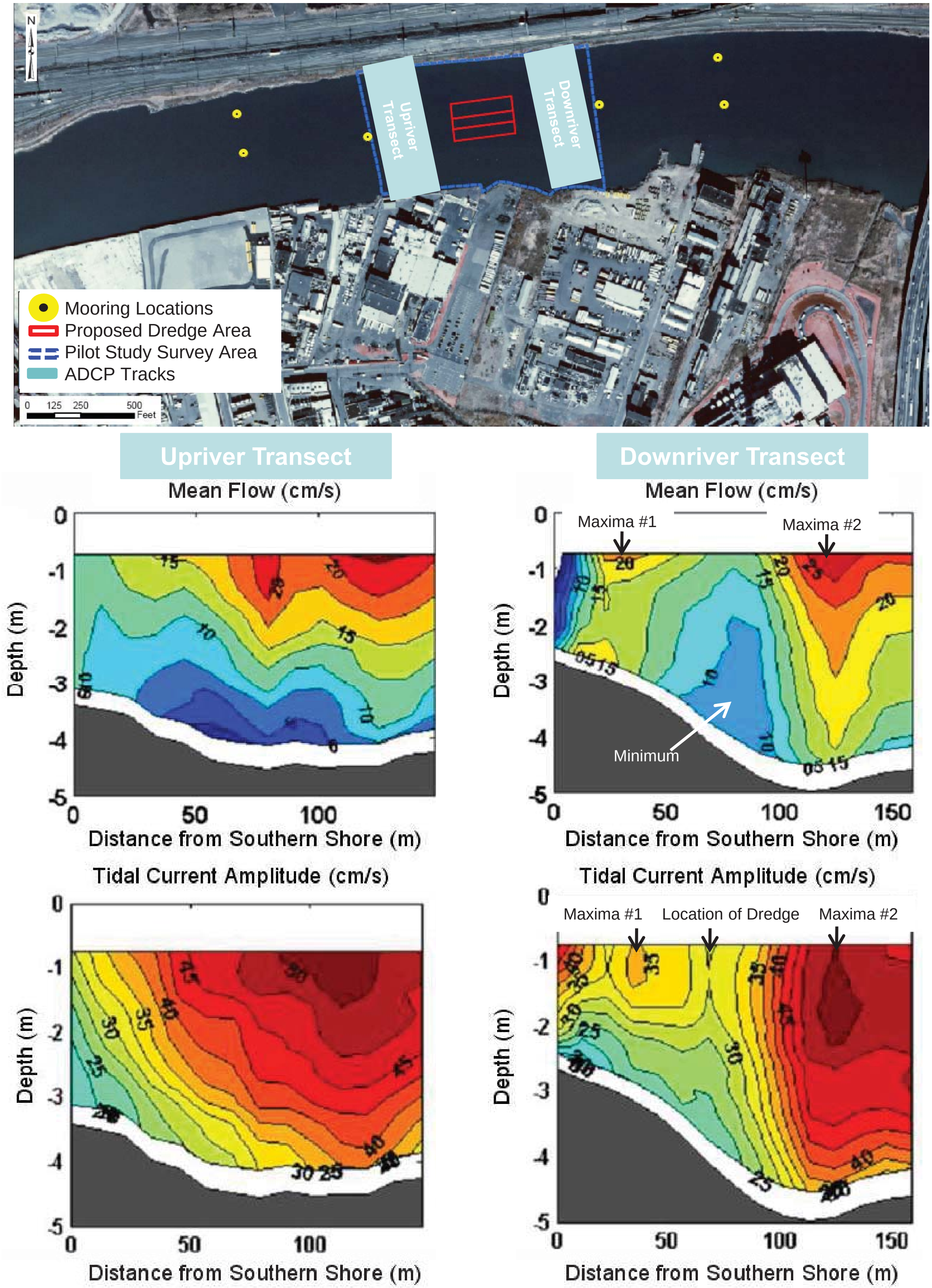
Figure 8-14



Principal Component 1 versus Principal Component 3 for the LISST Data Collected on Mooring 3 and Mooring 4

Lower Passaic River Restoration Project

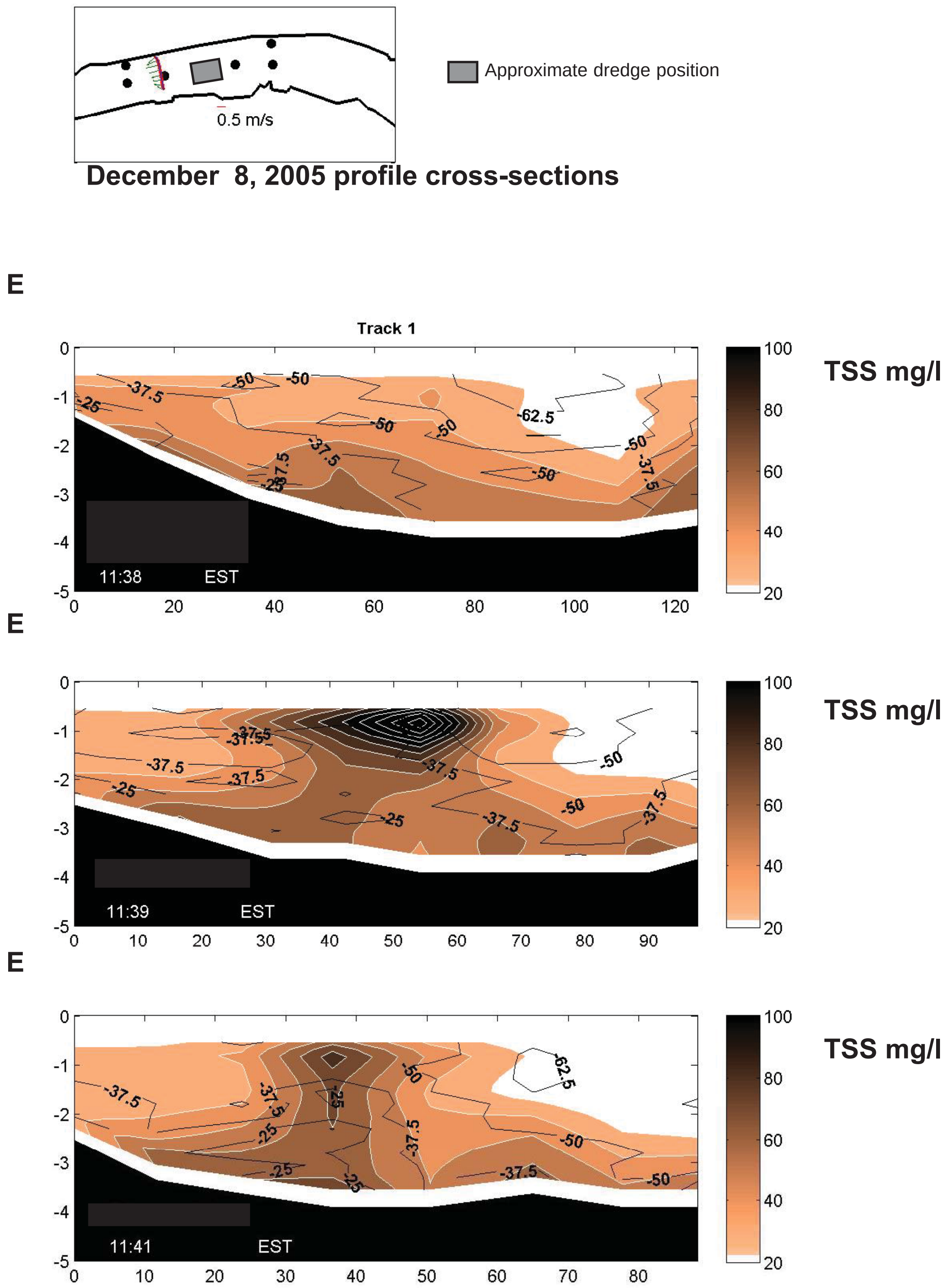
Figure 8-15



Results of Harmonic Analysis

Lower Passaic River Restoration Project

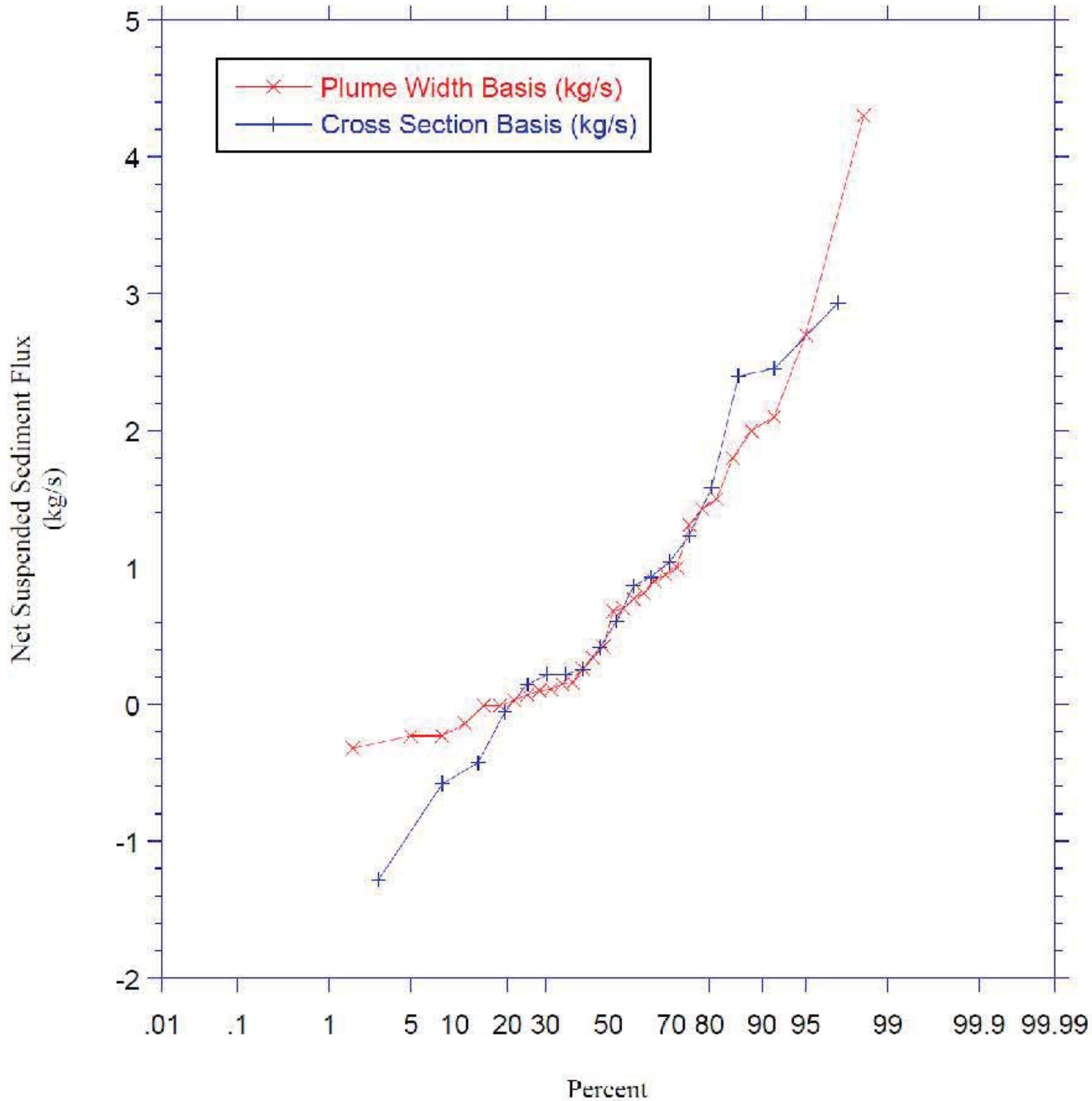
Figure 8-16



Intermittent Suspended Sediment Fluxes along a Near-Field ADCP Transect

Lower Passaic River Restoration Project

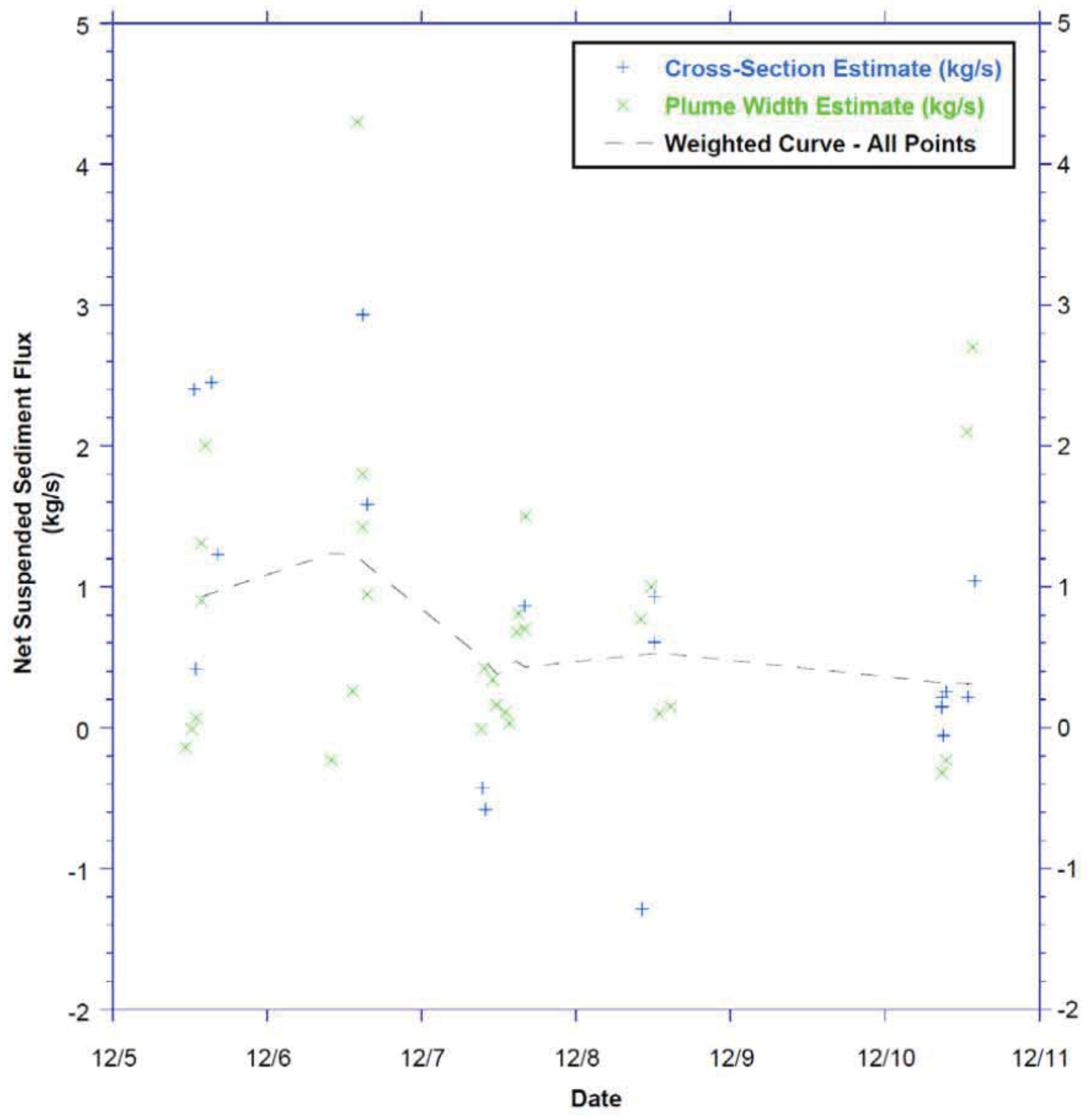
Figure 8-17



Probability Distribution for Plume-Width
and Cross Section-Based Net Suspended Sediment Flux

Lower Passaic River Restoration Project

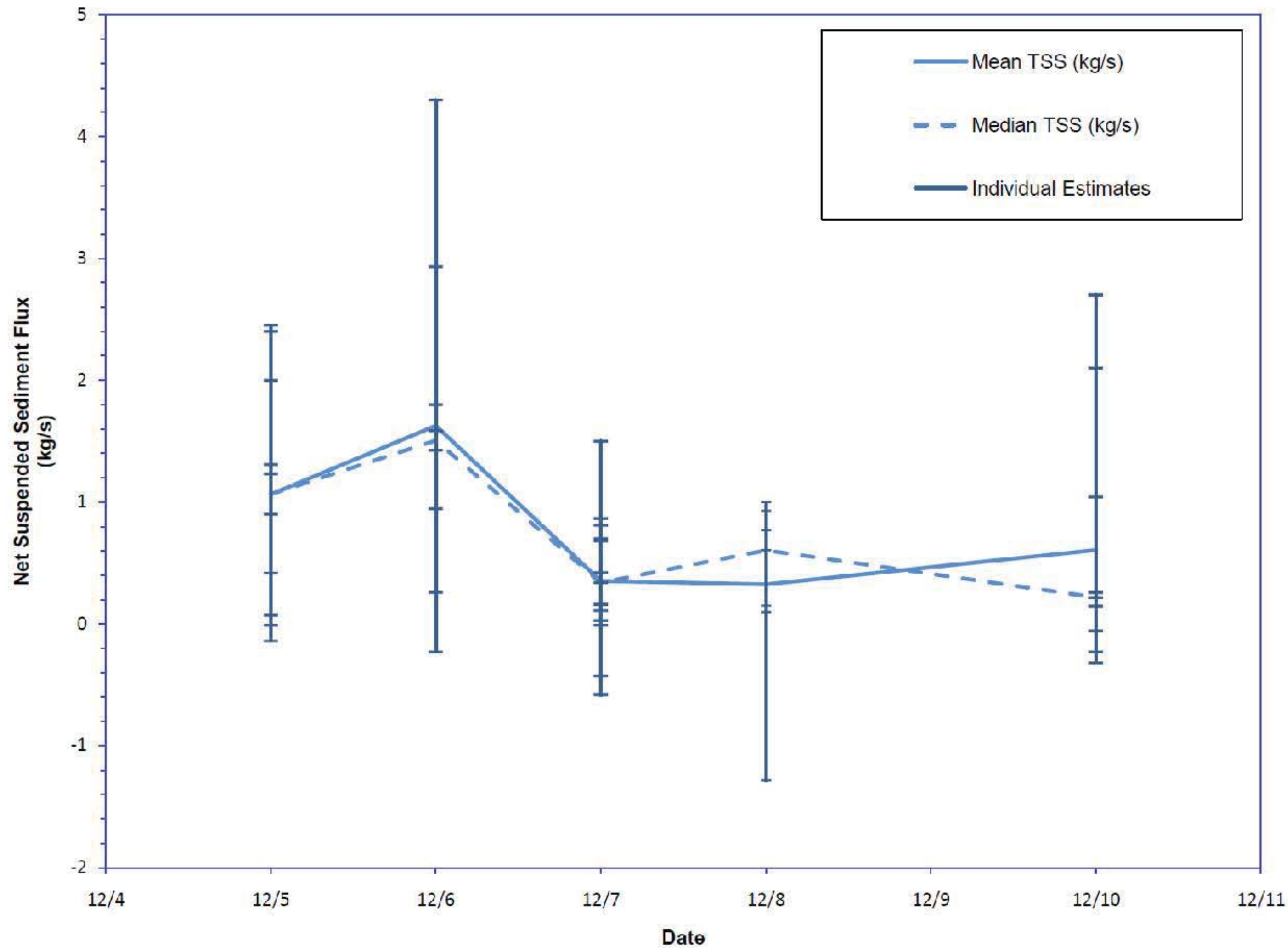
Figure 8-18



Individual Estimates of Net Suspended Sediment Flux due to Dredging and Daily Weighted Average Values

Lower Passaic River Restoration Project

Figure 8-19



Range Plot of Estimated Net Suspended Sediment Flux due to Dredging with Daily Mean and Median Values

Lower Passaic River Restoration Project

Figure 8-20

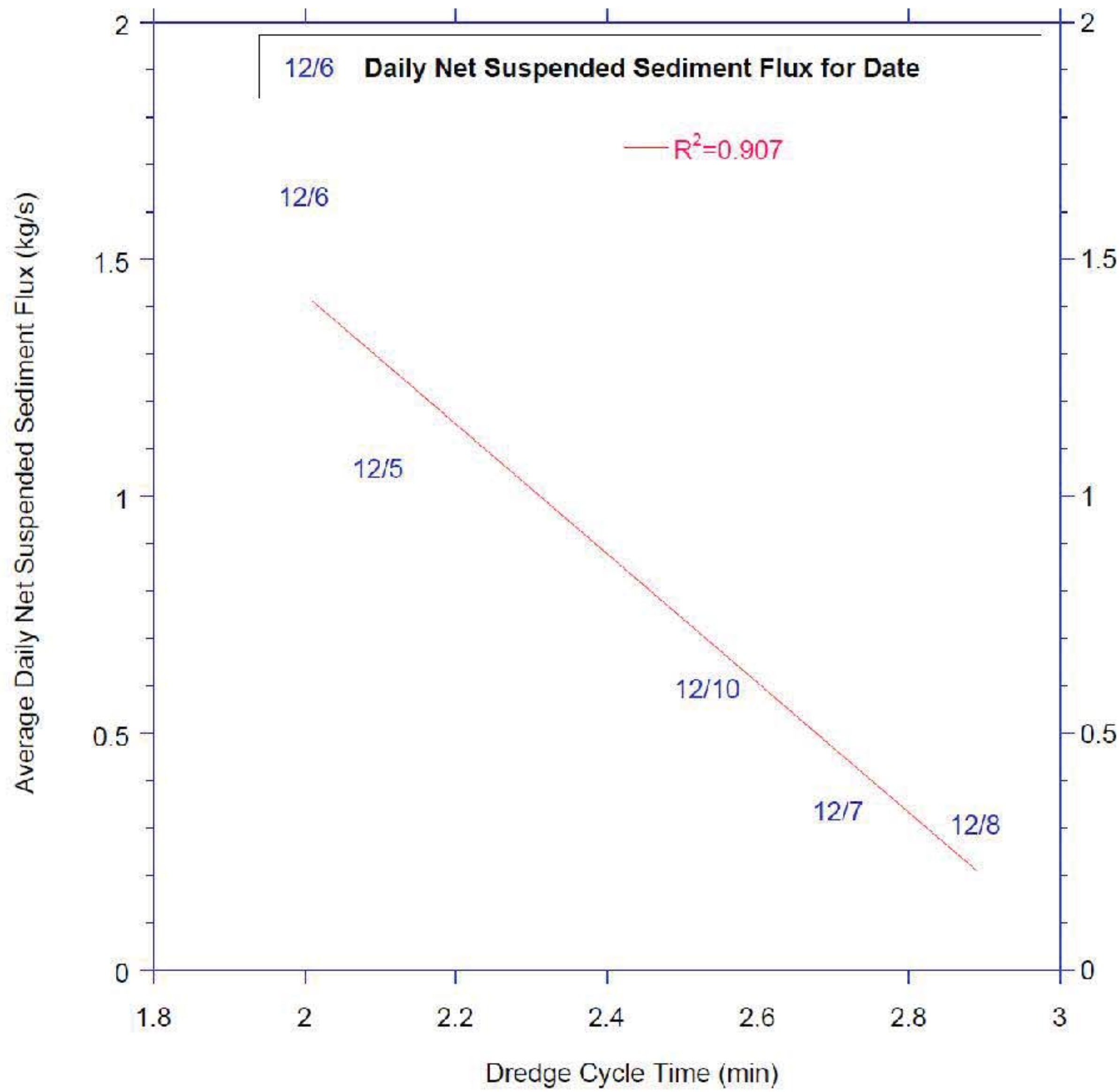
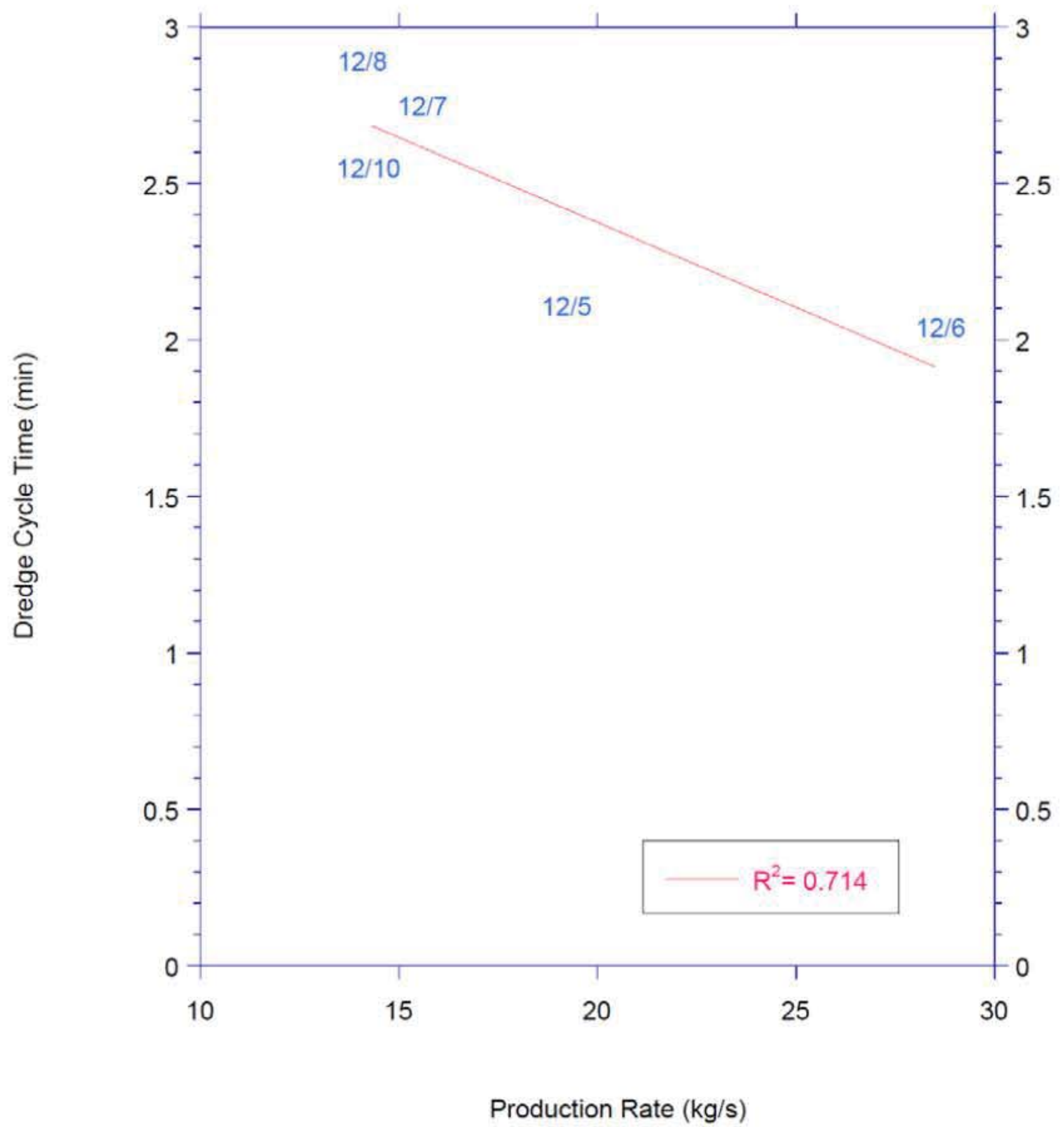


Figure 8-21

Correlation of Net Suspended Sediment Fluxes with Dredge Cycle Time

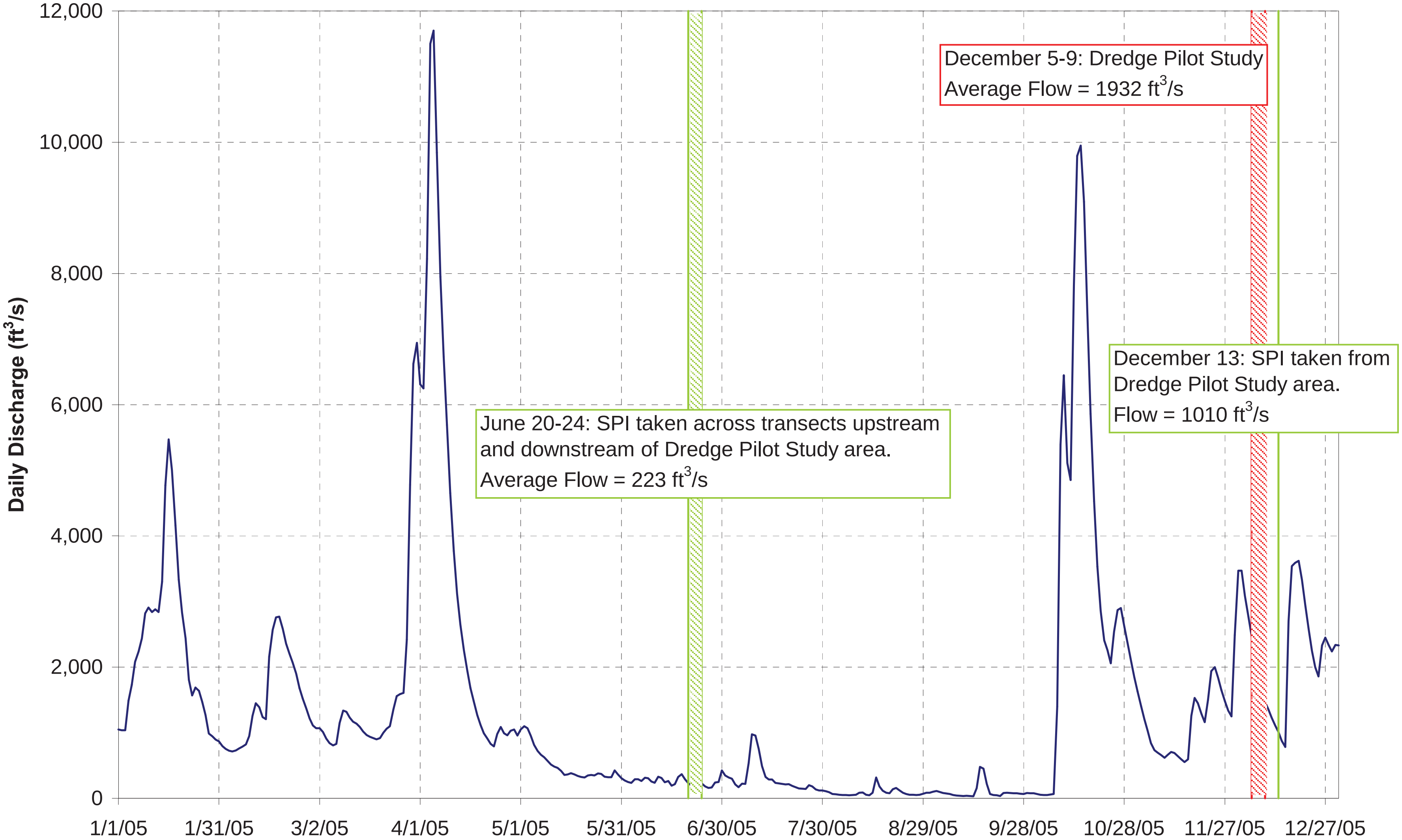
Lower Passaic River Restoration Project



Mean Daily Suspended Sediment Production Rate
versus Mean Dredge Cycle Time

Lower Passaic River Restoration Project

Figure 8-22



Lower Passaic River Flow at Little Falls, New Jersey

Lower Passaic River Restoration Project

Figure 8-23